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ASPEN FOREST VEGETATION IN A PORTION OF THE EAST CENTRAL ALBERTA PARKLANDS.

by

ELIZABETH JANE SCHEFFLER

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PLANT SCIENCE

EDMONTON, ALBERTA

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ASPEN FOREST VEGETATION IN A PORTION OF THE EAST CENTRAL ALBERTA PARKLANDS, submitted by Elizabeth Jane Scheffler in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

A study was initiated in the Kinsella region of the east-central Alberta parkland to investigate interrelationships of topography, soil and aspen (*Populus tremuloides*) vegetation. The rate of invasion of grassland by *Populus tremuloides* was also studied.

A reconnaissance approach was taken the first summer (1970), a more intensive ecological study followed in the summer and fall of 1971. Six groves were sampled using a stratified random method of plot location. Data were collected on species canopy coverage, *Populus tremuloides* height, age, diameter and basal area. Slope position, degree and aspect were recorded and soils were sampled for nutrient and texture analyses. Legal land surveys of 1903 were compared with aerial photographs of 1963 to estimate rate of aspen invasion.

Vegetation data were analyzed by cluster analysis and ordination. Although four basic community types were recognized, the vegetation within the *Populus tremuloides* groves showed enough gradational pattern to be considered a continuum. The continuity illustrated by the plot ordination and the cluster analysis and ordination was partly ecological and partly due to methods of data collection and analysis.

Populus tremuloides growth, judged in terms of basal area, height and age, was found to be least favourable on south-facing aspects and on the lowest slope position. The largest and oldest trees were found at a distance upslope from the slough edge corresponding to the region in which local ground water recharge patterns gave way to discharge patterns. This was the break in the slope where the soils showed variable degrees of gleying and recarbonation.

The *Populus tremuloides* invasion of 7.6 m/km/year into grassland was considered high; it was felt that ecological factors favoured continued expansion of *Populus tremuloides*. However, checks were being provided by man's agricultural activities.

Sloughs occupied some of the depressions in the dead ice moraine landscape. Around the sloughs and extending progressively upslope were *Salix* spp., *Salix-Populus tremuloides*, large *Populus tremuloides*, medium *Populus tremuloides*, small *Populus tremuloides* and eventually shrub and grassland communities. Associated with the topographical and successional (forest age) gradients were gradients of soil subgroup and moisture content, from Humic Eluviated Gleysols at the moist slough edge to Dark Brown Chernozems at the drier grassland positions. Soil nutrients also showed certain patterns but their distributions were influenced by other edaphic factors as well as topographical and environmental factors.

Interrelationships between *Populus* growth parameters and selected species within the groves, between species and topography and between soil and topographical parameters were described. More detailed studies are needed to develop numerical and/or cause-effect relationships for any combination of the above parameters.

ACKNOWLEDGEMENTS

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INTRODUCTION

In central Alberta and Saskatchewan and in southern Manitoba there occurs an extensive vegetation type known as the aspen parkland. The type is so named because of the interspersion of aspen groves and grasslands resulting in a park-like appearance. In the central part of the belt the two types of vegetation dominate practically equal areas, the *Populus tremuloides*[1] community occupying the more moist and sheltered situations, the prairie occurring on the drier and more exposed positions. Near the southern limit of the parkland, prairie vegetation occupies the larger proportion of the region, with wooded vegetation being mainly confined to the margins of sloughs, banks of streams and north-facing slopes of deep ravines and river valleys. Towards the northern and western limits of the parkland on the other hand, the bulk of vegetation is comprised of *Populus tremuloides* while prairie vegetation is restricted to steeper and drier south-facing slopes (Moss, 1932).

The grassland component of the parklands is comprised of a number of communities. According to Wroe (1971), the *Festuca scabrella* community is most extensive

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[1]Nomenclature of the plants follows Moss (1959).

and occupies a mesic location in the landscape. Southern exposures of hills are occupied by the *Stipa spartea* var *curtiseta-Festuca scabrella* community, while the *Stipa spartea* var *curtiseta-Artemisia frigida* community occupies upper south-facing slopes. Shrubs such as snowberry (*Symphoricarpos occidentalis*), wild rose (*Rosa* spp.), raspberry (*Rubus strigosus*) and silverberry (*Elaeagnus commutata*) occur as margins between the grassland and *Populus tremuloides* groves or as separate stands in the grassland.

The aspen groves are comprised of *Populus tremuloides* and to a lesser degree, balsam poplar (*Populus balsamifera*). Within an aspen grove there is much variation in understory species, especially in the distribution of the shrubs *Amelanchier alnifolia, Symphoricarpos occidentalis, Rubus strigosus, Rosa woodsii* and *Rosa acicularis*. Grass, grass-like species and forbs comprise the lower layer of the *Populus tremuloides* community.

A number of investigations of *Populus tremuloides* growth characteristics have been made in the north central United States, Saskatchewan and Alberta. *Populus tremuloides* is adapted to a wide range of ecological conditions, including dry knolls, moist river flats and soils of various textures (Moss, 1955). The best growth has been found to be on loam soils in a moderately moist habitat (Gates, 1930; Kittredge, 1938; Maini, 1960; Moss, 1955 and Stoeckeler, 1960). Water relations, influenced by soil textures, precipitation, ground water, aspect and topography are felt

to be of primary importance to the growth of *Populus tremuloides* (Fralish, 1972; Graham *et al.*, 1963; Meyer, 1956; Stoeckeler, 1960; Voigt *et al.*, 1957 and Wilde and Pronin, 1949). The life history of *Populus* has also been the subject of investigation in the past (Bird, 1930, 1961; Day, 1944; Gifford, 1966; Kirby, 1957; Maini, 1960, 1968; Moss, 1938; Zalasky, 1970). However, the structure of the *Populus tremuloides* community in the Canadian aspen parkland has been relatively unstudied. Some work has been done on species composition and general distribution (Hilton and Bailey, 1974; Maini, 1960; Moss, 1932 and Wroe, 1971) but there was a need for a clearer understanding of the relationships of the vegetation to the environment. A closer study of soil characteristics and the specific soil types associated with the *Populus tremuloides* community was essential to this understanding and would be of value in the continuing study of *Populus tremuloides* invasion into grassland.

Prompted by the gap in the scientific literature, a study was initiated with the following objectives:

1. to investigate species composition and interrelationships within aspen groves in the east central Alberta parkland.
2. to investigate the relationship of topography and soil to growth of *Populus tremuloides*.
3. to investigate the interrelationships of vegetation, topography, and soil within the aspen groves and

4. to investigate the successional status of *Populus tremuloides* in the east central Alberta parkland.

DESCRIPTION OF THE STUDY AREA

The study area was located on the University of Alberta ranch at Kinsella, 153.6 km. south-east of Edmonton, Alberta. Geologically, Kinsella bedrock is in the Pale Beds Division (Wyatt *et al.*, 1944). During the recession of Keewatin glaciation, 15,000 years ago, the area was overlain by heavy textured till of the Viking moraine. This till often contains a high percentage of medium and coarse sand. Soil developed from this till is of a medium loam texture, with few to many glacial stones. Mosaics of Dark Brown, Black and Dark Grey Chermozemic soils are found over much of the area with gleysolic soils in the vicinity of the depressions. The hummocky disintegration moraine gives the area a knob and kettle effect with some of the depressions being quite large, holding water throughout the driest months. The very alkaline sloughs have salt encrusted shorelines they appear to be the terminal drainage basins for the many smaller, less brackish sloughs located at a slightly higher elevation.

The climate of the area is classified as Dfb, humid microthermal with cool summers (Trewartha, 1968). The average precipitation is 38 cm per year with 88.9 cm

of snow in winter and the remainder falling as rain mainly in June and July. The mean monthly minimum temperature for the coldest month (January) averages -23°C and the mean maximum for the same month is -13°C. Summer minimums average 8°C and maximums 19°C, with July being the warmest month. There are approximately 115 frost free days in the growing season. Prevailing winds are from the west and northwest (Wyatt *et al.*, 1944).

The vegetation in the study area is typical Alberta parkland as described by Moss (1955). The major grassland community in the parkland is the *Festuca scabrella* association (Moss and Campbell, 1947). On exposed over-grazed knolls and south-facing slopes *Stipa spartea* var. *curtiseta*, *Bouteloua gracilis* and *Agropyron* spp. predominate. The lowest slope positions are often occupied by sloughs or wet depressions. Fresh water sloughs are generally dominated by *Carex* spp. and grasses which include *Glyceria grandis*, *Poa* spp., *Beckmannia schizachne* and *Hordeum jubatum* (Hilton, 1970). However, when the sloughs are brackish, the shorelines are heavily encrusted by salts and bare of vegetation except for the following halophytic plants: *Distichlis stricta*, *Puccinellia nutalliana*, *Eleocharis palustris*, *Salicornia rubra*, *Chenopodium rubrum* and *Suaeda depressa* (Bird, 1961).

Around the fresh water sloughs are found *Salix* communities, including basket willow (*Salix petiolaris*)

between high and low water levels and pussy willow (*Salix discolor*) at the high water level (Bird, 1961). In progression away from the *Salix* communities are found communities dominated by *Populus tremuloides*. A shrub community dominated by *Symphoricarpos occidentalis* is often found between the *Populus tremuloides* and grassland communities (Wroe, 1971).

METHODS

I. Terminology

"Plant community" in this study was used as a general term referring to a homogeneous group of plants having a characteristic pattern of species composition and dominance (Daubenmire, 1966). In the study area, two major communities encircled most depressions or sloughs. In closest proximity to the slough was a *Salix* spp. dominated community which was replaced further upslope by a community dominated by *Populus tremuloides*. Together these two communities comprised an "aspen grove." The groves were located in the mesic habitat provided by the mid-and lower-slope positions in the rolling topography. Groves were replaced upslope by the grassland community and downslope by the sedge (*Carex* spp.) community of the moist depression.

The canopy coverage concept used in this study followed that of Daubenmire (1959) where canopy coverage was defined as "the percent of ground covered when a polygon, drawn about the extremities of undisturbed canopy of each plant, is projected upon the ground and all such projections on a given area are summed."

The species with the highest canopy coverage in each study unit was considered the dominant species. Subdominants were species with a canopy coverage of at least 60 percent of the dominant. Tentative communities and clusters were defined by the dominants and subdominants of each stratum. A stratum was a layer of vegetation that was distinguished,mainly by height above the ground and plant composition, from other layers of vegetation in the study unit. There were basically three strata in the communities studied--tree, shrub and herbaceous. A stratum was included in the definition of a cluster or community only if the dominant species for that stratum had a cover value of at least 38 percent. Codominance was expressed by a dash (-) and subdominance by parentheses ( ) while strata were separated by a slash (/).

II. Selection Criteria

After studying the aspen groves on the ground and on aerial photographs, ten groves were selected for study. The groves selected appeared to be representative of most groves in the study area. To facilitate the objectives of the study, the groves selected met the following criteria:

1. the *Populus tremuloides* appeared to have expanded vegetatively from the edge of a water filled depression or slough

2. at least two age groups of *Populus tremuloides* and *Salix* were present
3. the groves could be recognized as a distinct unit, and
4. there was little or no disturbance caused by livestock or man's activities.

The third criterion was added to eliminate complexities that the author felt would arise if contiguous groves were studied before a basic description of individual groves was obtained. However, groves meeting all four criteria were scarce in the study area and the third criteria was not always met.

III. Snow Depth

Snow depth was recorded in the winter of 1970 and 1971 to assist in the interpretation of summer soil moisture data. Transects were located in two groves and snow depth was measured with a metal rod at ten pace intervals downslope from grassland to slough edge. Measurements were taken once a month in January, February and March 1970 and November to March in 1971.

IV. Vegetation

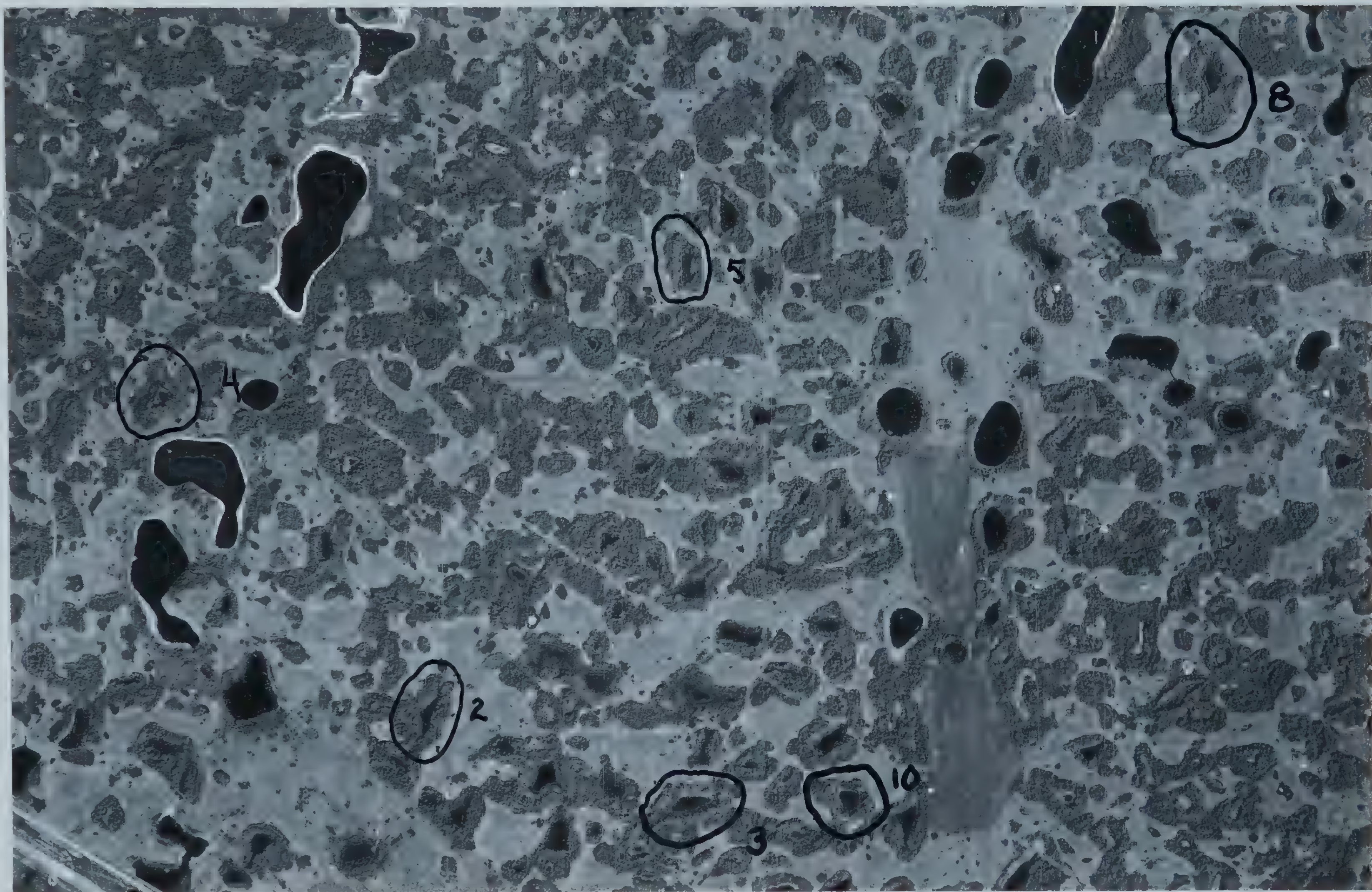
A reconaissance study of the selected groves was undertaken in the summer of 1970. *Populus tremuloides*

was divided into three size classes -- small 0.89 cm DBH, medium 9-17.8 cm DBH and large > 17.8 cm DBH where DBH was diameter at breast height. Individual stands of plant communities were recognized on the basis of *Populus* size class, and dominant understory vegetation. Ocular estimates were made of canopy coverage for all species within a stand in each of six groves (Figure 1) following the method described by Daubenmire (1959). A seven class scale was used:

Class	Range in Cover (%)	Class Mid Point
1	0 - 1	0.5
2	1 - 5	3
3	6 - 25	15
4	26 - 50	38
5	51 - 75	63
6	76 - 95	85
7	96 - 100	98

A stratified random method of sampling was used in 1971. Each of six groves was divided into 4 pie-shaped segments along the northwest, southeast, northeast and southwest axes. Within each quarter, an angle was randomly chosen between 0 and 90 degrees. This angle was extended as a belt transect from the centre outward to the edge of the grassland. Each belt transect was divided into 6 equal segments and a 1.5 x 6.6 m plot was located

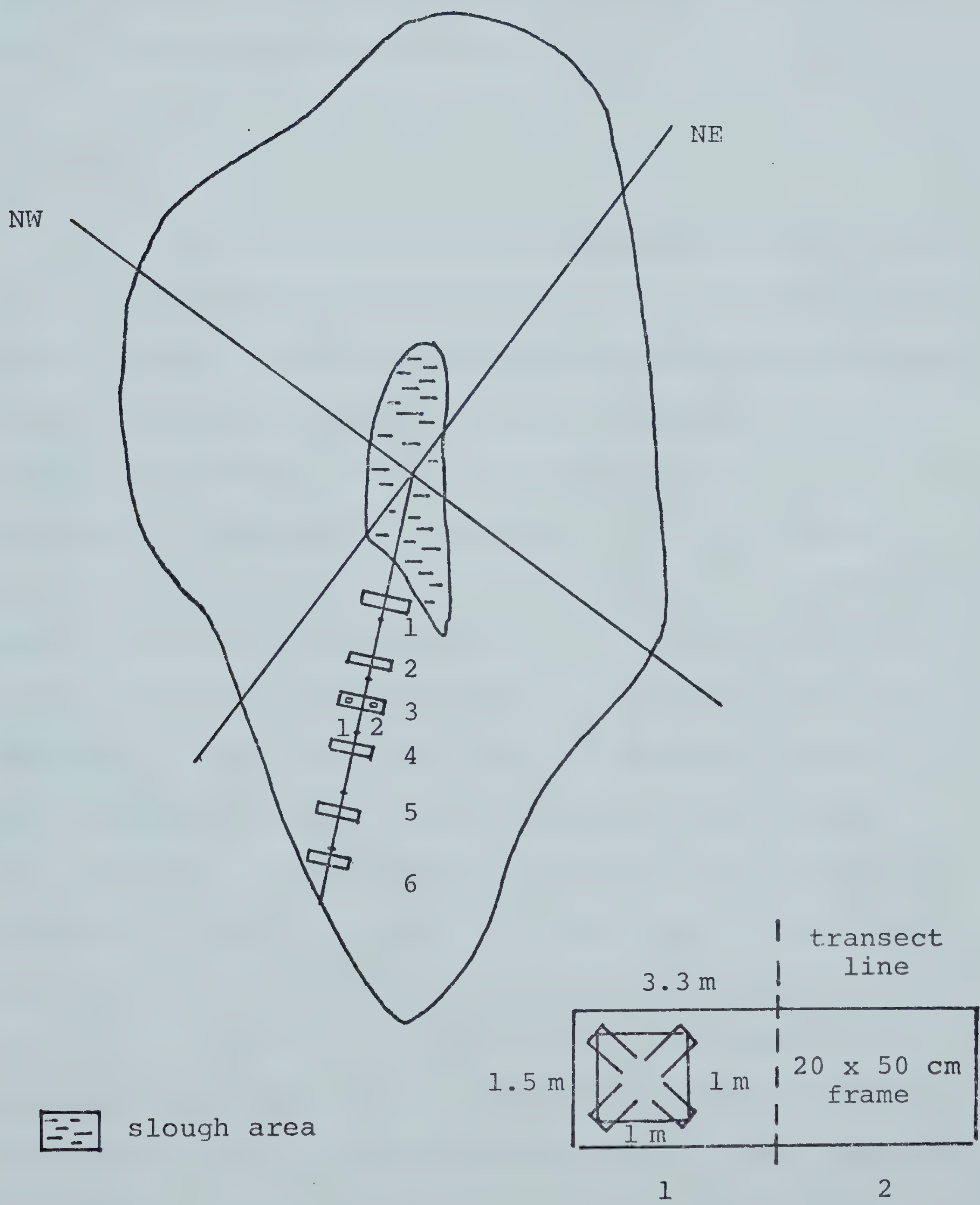
Figure 1. Aerial photograph of the study area, showing location of the six groves studied, scale 1 cm = 0.13 km.



randomly within each segment (Figure 2). Within each 1.5 x 6.6 m plot, two 1 m^2 quadrats were randomly located, one on either side of the center line. At all four staked corners of the one m^2 quadrat, a 20 x 50 cm plot frame was centered and oriented inward toward the diagonally opposite corner.

Vegetation data collected within each one m^2 quadrat included a list of vascular plant species and canopy coverage of each. The cover was recorded using the 20 x 50 cm frames and a scale slightly different from that used in 1970. An additional class was inserted between 3 and 4. That is the range of class 3 became 5 - 15%, mid point 10 and class 4 became 15 - 25%, mid point 20. The remaining 4 classes were unchanged. Diameter at breast height of the closest tree to each of two corners of the one m^2 quadrat was measured. Two trees, representing the average tree diameter in each of the six segments per slope, were cut down in order to estimate age by ring count and to measure height. For half of these trees, diameter at breast height was also measured. A reading for basal area was taken at the center of each quadrat using a prism. Bitterlich angle gauges (prisms are modern equivalents) measure stem cover by the point frequency method. This gives an indication of species dominance, an important parameter in vegetation ecology (Mueller-Dombois and Ellenberg, 1974).

Figure 2. Location of sample plots within a grove, 1971. Only one of the four transects is illustrated.



Field notes from the 1903 Legal Land Survey (Saint Cyr, 1903) on and near the study area were compared to 1963 aerial photography of the same area. By comparing the area occupied by brush in 1903 to that in 1963, the rate of spread of brush could be estimated. Twenty-six 1.6 km transects were studied.

V. Soils

Soil moisture data were collected in June, July and August 1970 using the gravimetric method (Ehrenreich, 1962). Water content was measured as a percent by weight. Sample sites were located along the transects used to record snow depths. Soil temperatures were recorded at each moisture sampling location by using a metal dial thermometer with a 15 cm probe. In order to reduce possible diurnal effects, all readings were taken in the morning. In 1971, temperature readings were taken in August at the center of each 1 m^2 quadrat. Soils were characterized and nutrient samples taken in both field seasons. Pits were dug along the soil moisture transects in 1970 but for 1971, a soil pit was dug for each of the 1.5 x 6.6 m plots at a site representative of the two 1 m^2 plots in the macroplot. Soil characters determined included type of horizon, depth, texture, consistence, color, structure and depth to lime. Samples

of each horizon were collected and sent to the Soil and Feed Testing Laboratory, Alberta Department of Agriculture. Tests included were: available nitrogen, phosphorus, potassium, sulphur, pH, salinity, sulphates, organic matter, free lime and texture. Samples were also collected in 1971 for texture analysis by the Bouyoucos (1951) method.[2]

VI. Topography

In 1971, slope position and degree were recorded for each one m^2 plot with the aid of an abney level. A profile was made of each of the four slopes in the six groves.

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[2]Some modifications of the Bouyoucos method were used. Particle size was done on a 50 gm oven-dried sample which was slaked in 100 ml of Calgon solution for at least 15 hours. A three minute mixing time was used consistently for all samples prior to being washed into the cylinders. Readings were taken at 40 seconds and 2 hours. Percent sand, silt and clay were calculated by the following method after correction for temperature and Calgon:

40 sec reading x 2 = % clay and silt

2 hr reading x 2 = % clay

100 - (% silt and clay) = % sand

(% silt and clay) - % clay = % silt

VII. Data Analysis

Association tables were constructed for vegetation data of 1970 to obtain a general picture of community types present. An ordination program developed by Pinchbeck (1972), based on the work of Swan *et al.* (1969), was used on both 1970 and 1971 sets of data. Interplot distances were not calculated using the earlier technique of Bray and Curtis (1957) but by Euclidian distance

$$D_{jh} = [\Sigma^n (X_{ij} - X_{ih})^2]^{1/2} \qquad \text{(Orloci, 1966)}$$

where $i = 1$

j and $h =$ two stands

$x_i =$ the i^{th} species score.

The method of chosing the first two reference stands for axis one has varied in the literature. Some of the methods include (a) the two most dissimilar stands (Bray and Curtis, 1957), (b) the most dissimilar stand and that with the least similarity to the first (Beals, 1960; Maycock and Curtis, 1960), (c) the most similar stand and that with least similarity to it (Stringer, 1969), and (d) the first axis being that which accounts for the highest proportion of the sum of squares for all interstand distances (Swan *et al.*, 1969). The method of axis selection used by Swan *et al.* (1969) was followed in this study. The positioning of remaining stands on the axes followed Beals (1960).

The clustering algorithm used was that of Carmichael *et al.* (1968) in which a similarity vector based on Euclidean distance was searched progressively for plots with highest similarity. Each point being considered for inclusion in a cluster had to meet four criteria based on difference between drop in average linkage and new average linkage, between drop in best single linkage and new single linkage and ratio of minimum similarity within the cluster to minimum similarity of point being considered and any point in the cluster. Computer programs used for clustering and ordination of clusters by a matrix of inter-cluster distances were developed by Pinchbeck (1972) and are found in the Range Management Laboratory, Department of Plant Science, University of Alberta. Correlation programs used on the data were obtained from Computing Services, University of Alberta. An arc-sin transformation was performed on all canopy coverage data prior to analyses.

The 1970 vegetation analyses used species data collected from individual stands 30 meters by six to nine meters. In 1971 the unit of measure was a 1 m^2 plot. For each species, the canopy coverage value used was the mean derived from the four 20 x 20 cm frames located within the 1 m^2 plot. Analyses using canopy coverage were therefore based on input from 48 plots in each grove.

RESULTS

I. Vegetation

A. Species Distribution and Ordination

The dominant species of the upper stratum of most community types within the aspen groves was *Populus tremuloides* (Table 1). The size and age of this dominant varied among community types although the majority of the trees were between ten and forty years old. The major subordinates in the understory were *Rosa woodsii* and *Symphoricarpos occidentalis* in drier areas and *Salix* spp., *Rubus strigosus* and *Carex* spp. (mostly *Carex prairea*) in moist to wet areas. The common forbs throughout the aspen groves included: *Galium boreale*, *Pyrola asarifolia*, *Viola adunca*, *Fragaria virginiana* var. *glauca*, *Smilacina stellata* and *Anemone canadensis*. A continuum of species was apparent along the topographical and moisture gradient existing from hilltop to slough edge. In all four groves there was a similar gradual change in species and species richness that corresponded to increasing proximity to the slough edge (Appendices 1 - 4).

In the *Salix* dominated communities, the canopy coverage of species such as *Rubus strigosus*, *Carex* spp., *Poa* spp., *Calamagrostis* spp., *Aster hesperius*, *Stachys*

TABLE 1

Mean Cover Values (%) for Common Plant Species[a] of Four Main Community Types Sampled in Four Aspen Groves at Kinsella, Alberta, 1970.

Community		s Potr/ Syoc[b]	m Potr/ Syoc(Rowo)	l Potr	Salix/ Carex
Species	N = Code	16	16	15	7
Festuca scabrella	*Fesc*	8	1	7	
Amelanchier alnifolia	*Amal*	2	9	3	
Aster laevis	*Asla*	1	4	6	
Pyrola asarifolia	*Pyas*		4	5	
Ribes oxyacanthoides	*Riox*		2	12	
Viola adunca	*Viad*	6	7	7	
Galium boreale	*Gabo*	6	4	4	
Smilacina stellata	*Smst*	1	6	5	
Agropyron spp.	*Ag* sp.	9	7	12	1
Rosa acicularis	*Roac*	3	5	8	4
Arenaria lateriflora	*Arla*	3	2	3	2
Populus tremuloides	*Potr*	93	90	79	12
Symphoricarpos occidentalis	*Syoc*	67	38	36	10
Rosa woodsii	*Rowo*	29	31	20	11
Fragaria virginiana	*Frvi*	12	6	7	12
Taraxacum officinale	*Taof*	2	2	4	9
Carex spp.	*Carex*	19	18	29	67
Anemone canadensis	*Anca*	8	6	9	7
Rubus strigosus	*Rust*	12	16	17	32
Poa spp.	*Poa* sp.	2	5	4	25
Salix spp.	*Salix*		2	18	88
Aster hesperius	*Ashe*		2	6	5
Stachys palustris	*Stpa*		1	3	15
Geum allepicum	*Geal*			1	10
Poa palustris	*Poapa*			2	26
Mentha arvensis	*Mear*			1	15
Scutellaria galericulata	*Sega*			1	2
Carex atherodes	*Caath*			1	23
Calamagrostis spp.	*Cal* sp.			1	20
Sonchus arvensis	*Soar*				8
Stellaria longifolia	*Stlo*				13

[a] Species with >5% canopy coverage in at least one community

[b] *Populus tremuloides* size classes: s - small 0 - 8.9 cm
m - medium 9.0 - 17.8 cm
l - large > 17.8 cm DBH

palustris, *Geum allepicum* and *Mentha arvensis* were more abundant than in *Populus tremuloides* dominated communities. Other species including *Viola adunca*, *Smilacina stellata*, *Amelanchier alnifolia* and *Rosa woodsii* showed decreased canopy coverage values in the moister habitats. Species more common to the grassland community were also found in the aspen groves. The presence of *Festuca scabrella* and *Elaeagnus commutata* was probably due to the recent invasion of *Populus tremuloides* onto grassland.

In order to illustrate the distribution of species within an aspen grove, cover values of selected species were superimposed upon the plane defined by the X and Y axes of the 1970 plot ordination (given in a later section).

The abundance of *Salix* spp. in many plots in which it did not reach a sub or co-dominant level was evident in Figure 3. High cover values for *Salix* spp. were found on the far left of the X axis. *Carex* spp. were found in all positions on the ordination field, however, highest cover values were associated with the plots dominated by *Salix* spp. *Carex atherodes* was predominantly associated with *Salix* spp. while *Carex prairea* was found under small, medium and large *Populus tremuloides* and *Salix* spp. *Carex obtusata* was also present especially under small *Populus tremuloides*. Since it was difficult to positively identify the latter two species in the vegetative stage, *Carex prairea* and *Carex obtusata* were lumped together as *Carex* spp.

Figure 3. Distribution of cover values of selected species on the XY axis of the ordination of plots, 1970.

3A. *Salix* spp.
3B. *Carex* spp.
3C. *Rubus strigosus*
3D. *Populus tremuloides*
3E. *Symphoricarpos occidentalis*
3F. *Rosa woodsii*
3G. *Rosa acicularis*
3H. *Ribes oxyacanthoides*

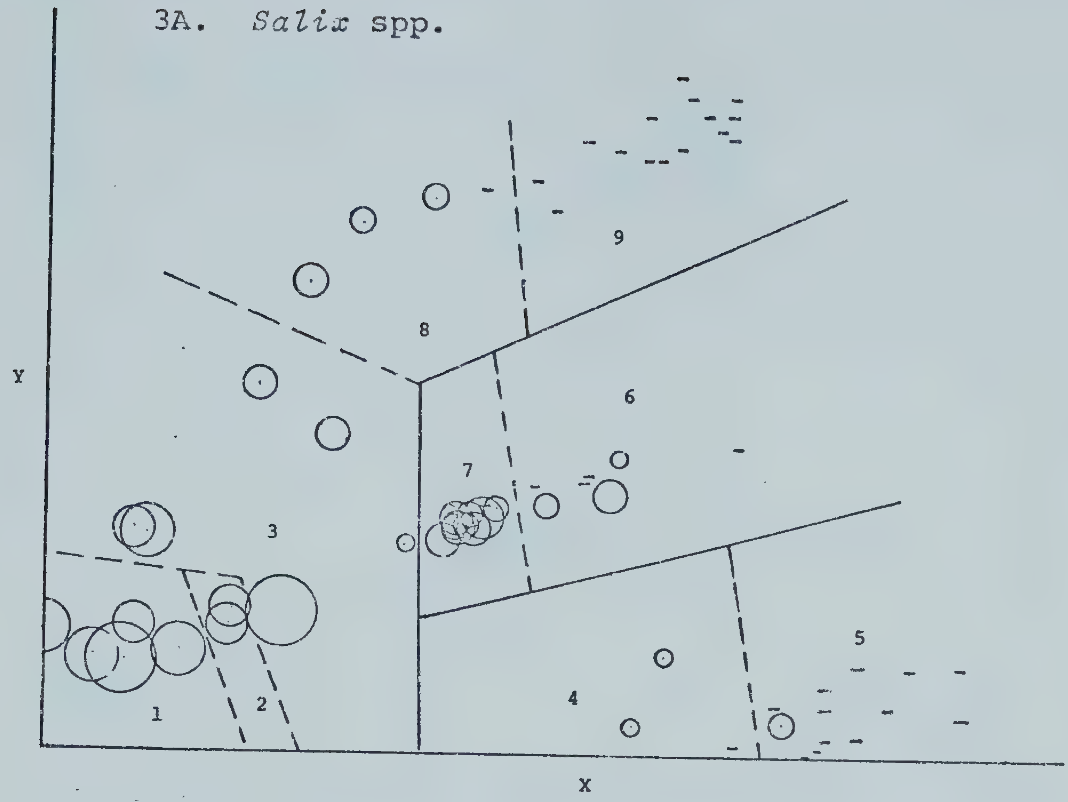
Code	Midpoint of Cover Class	Code	Midpoint
-	0	○	63
∘	1	○	85
○	3	◯	98
○	15		
○	38		

Community Type (as per Figure 3)

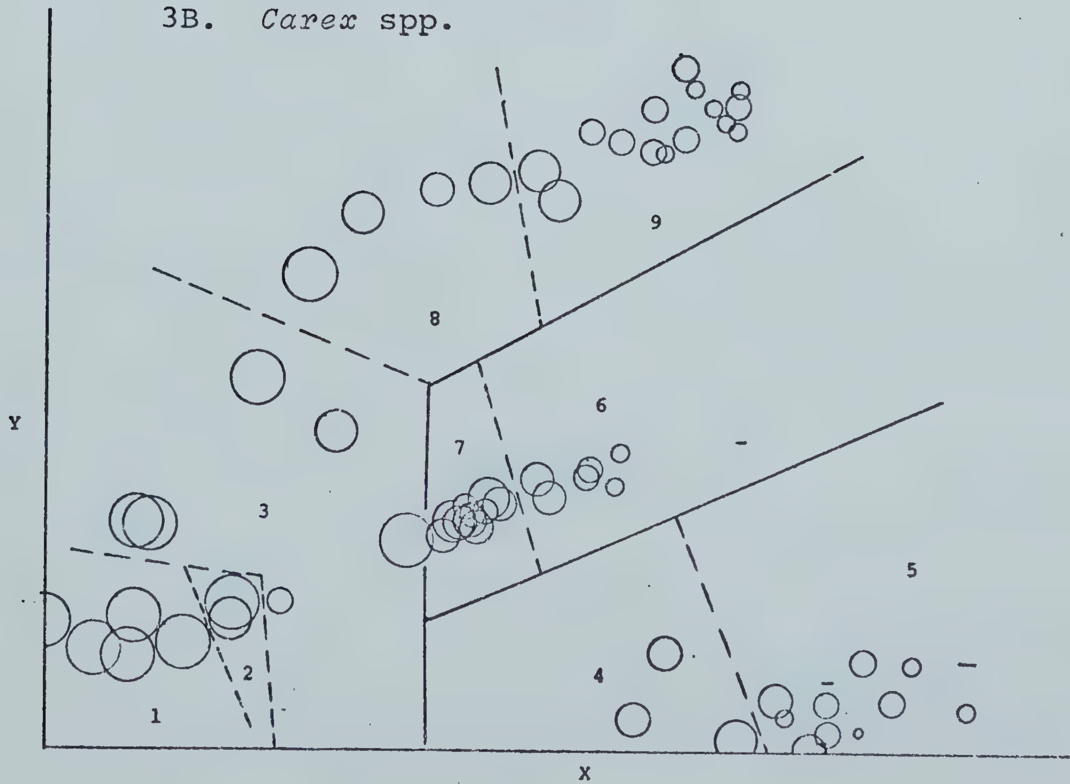
1 *Salix* spp./*Carex* spp.
2 *Salix* spp. (l *Populus tremuloides*)/*Carex* spp.
3 Ecotonal
4 m *Populus tremuloides*/gramineae
5 m *Populus tremuloides*/shrub
6 l *Populus tremuloides*/shrub
7 Ecotonal l *Populus tremuloides*, *Salix* spp./shrub
8 s *Populus tremuloides*/*Carex* spp.
9 s *Populus tremuloides*/*Symphoricarpos occidentalis*

s - small
m - medium
l - large

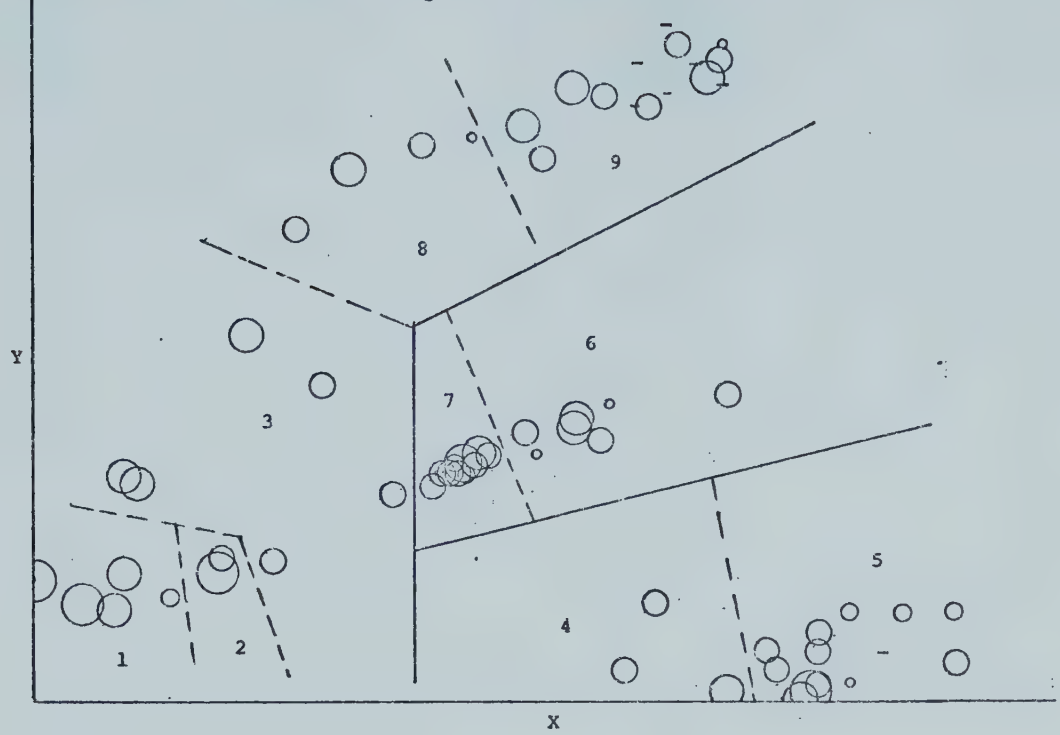
3A. *Salix* spp.



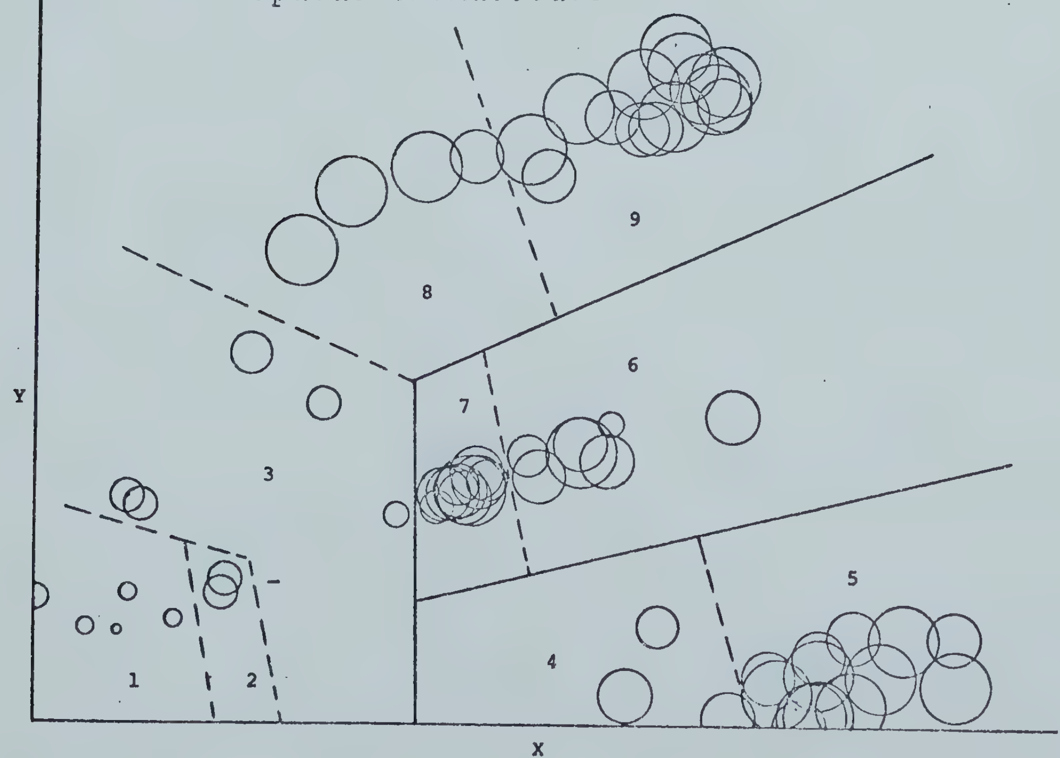
3B. *Carex* spp.



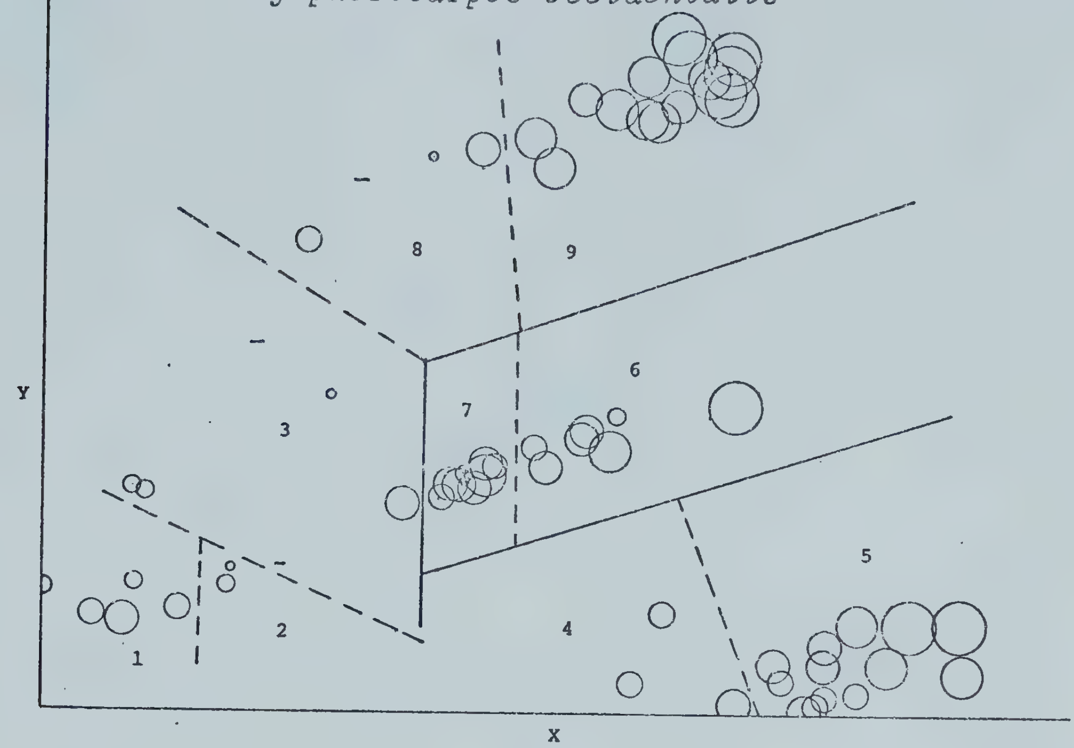
3C. *Rubus strigosus*



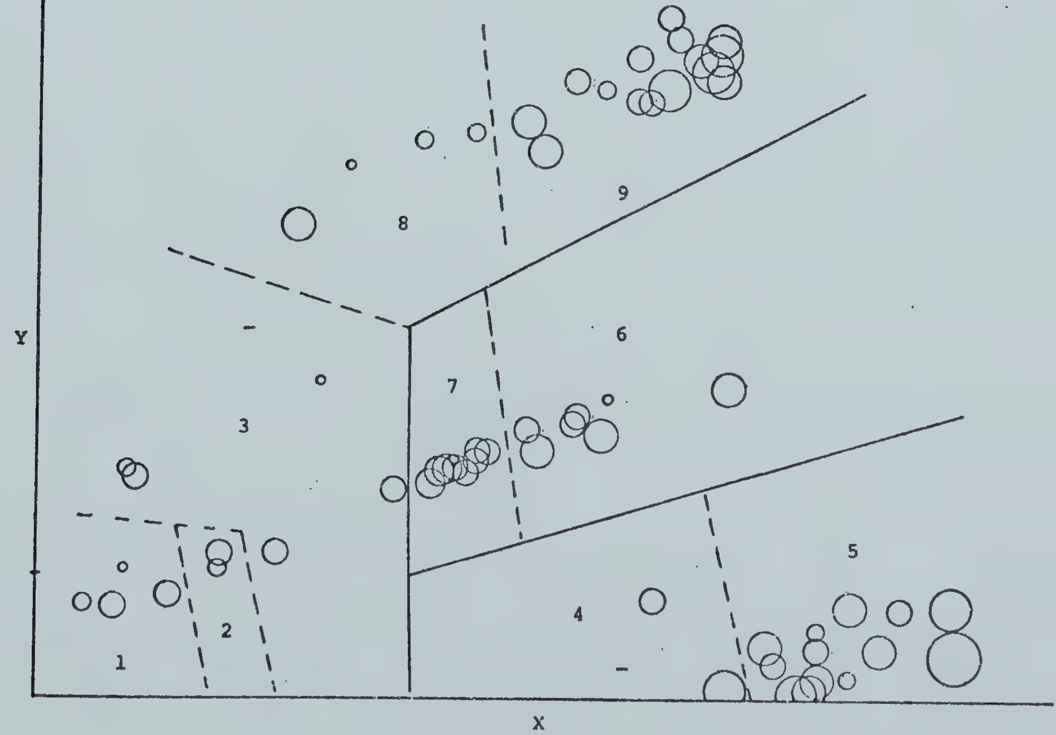
3D. *Populus tremuloides*



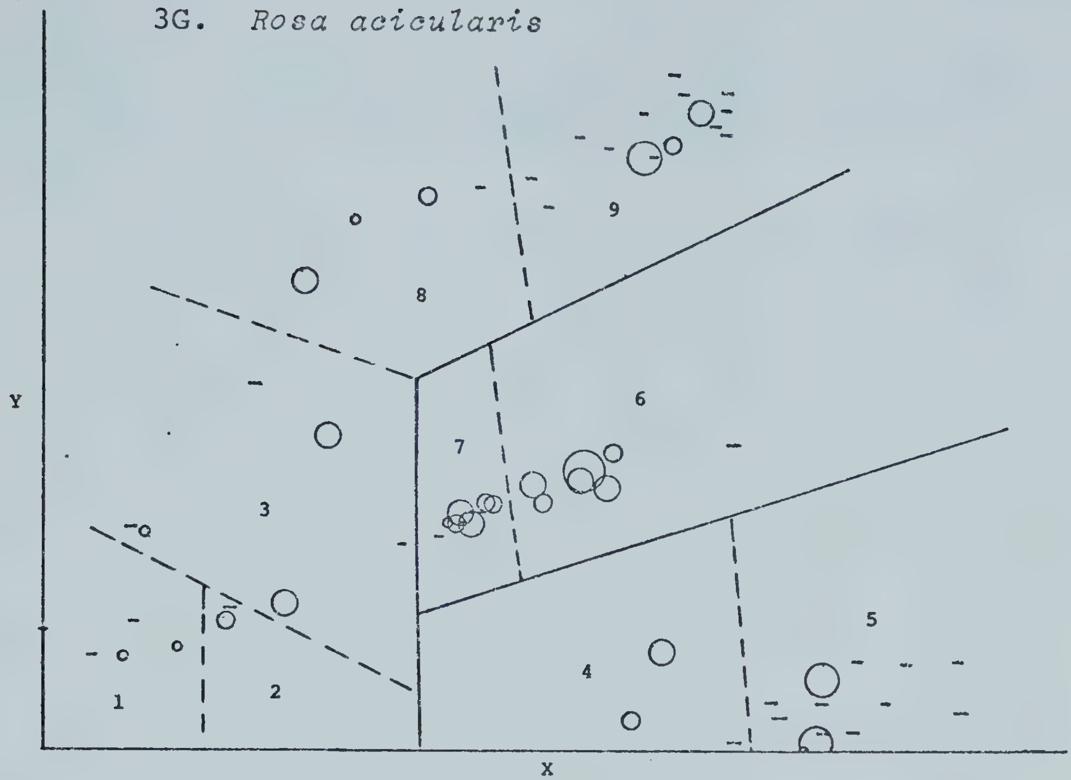
3E. *Symphoricarpos occidentalis*



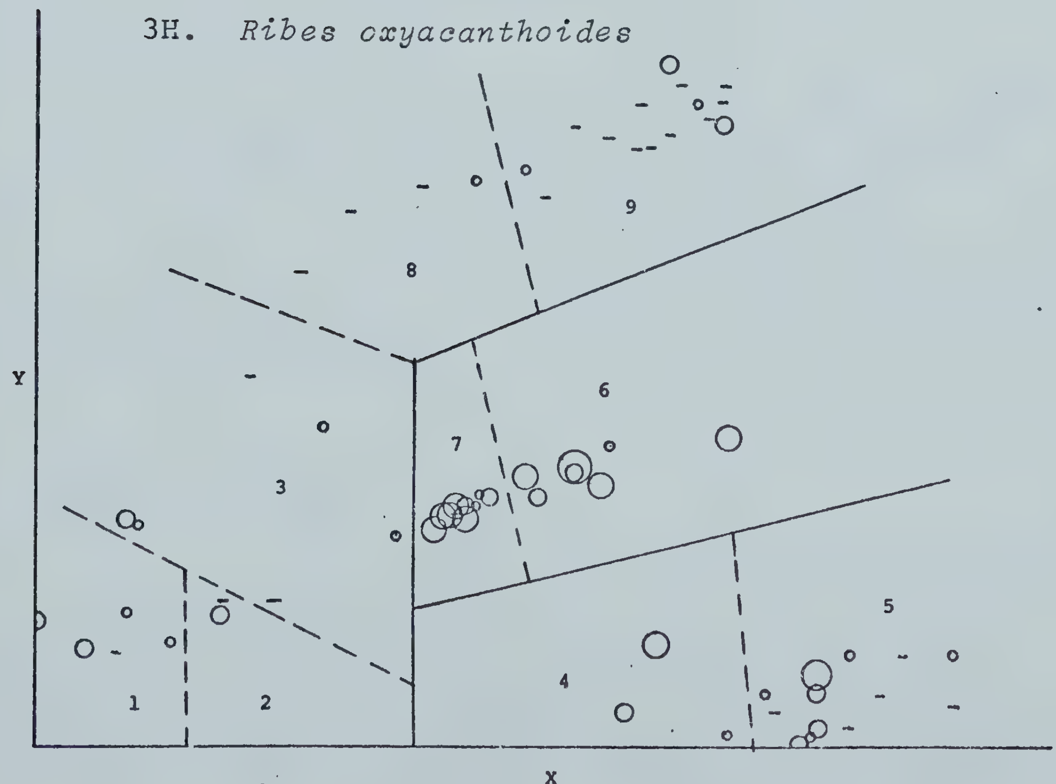
3F. *Rosa woodsii*



3G. *Rosa acicularis*



3H. *Ribes oxyacanthoides*



Rubus strigosus distribution also showed high cover values associated with *Salix* spp. domination on the far left of the X axis.

Although some *Populus tremuloides* was found on the far left of the X axis, the highest cover values were at the right of the X axis (Figure 3). *Symphoricarpos occidentalis* was also found in most plots, however, there was a definite gradient of cover values from low to high (wet to dry) along the X axis from left to right. *Rosa woodsii*, like *Symphoricarpos occidentalis*, had its highest cover as understory to small and medium *Populus tremuloides*, and declined towards the *Salix* spp. dominated left end of the X axis. *Rosa acicularis* showed consistently low cover values, and was predominatly associated with the older communities dominated by large *Populus tremuloides*. The distribution of *Ribes oxyacanthoides* was somewhat like that of *Rosa acicularis*, both occurring predominately as understory to large *Populus tremuloides*. The canopy coverage of *Ribes oxyacanthoides* did not reach values higher than 38 percent in any plot.

B. Cluster Analysis

The vegetation within each grove and among groves was compared by cluster analysis using cover values for species in each plot as the variables. Analysis of 1970 and 1971 data resulted in clusters differentiated predominantly on the basis of the following species: *Populus*

tremuloides, *Salix* spp. (*Salix discolor* and *Salix bebbiana*), *Symphoricarpos occidentalis*, *Rubus strigosus*, *Carex* spp. (mainly *Carex prairea*), *Rosa acicularis* and *Rosa woodsii*.

The clusters were ordinated in order to demonstrate the relationship of one cluster to another and to give a graphical representation of the vegetation in each grove. In the following figures, circles represent clusters comprised of two or more plots.

The intercluster distance was determined from the sum of the two cluster radii plus the distance between the nearest neighbours of the two clusters. The cluster radius was defined as one-half the maximum interplot distance which occurred within the cluster (Carmichael, 1970). The dotted boxed areas are approximate groups of single plot clusters by vegetation type.

1. Grove Two

Populus tremuloides was the dominant in eight of the nine main clusters (Figure 4, Table 2). The nineteen single plot clusters varied widely in their dominant species (Appendix 5). The X axis was considered to be one of decreasing soil moisture, (left to right), with the nine main clusters having little or no *Salix* spp., *Carex* spp., *Calamagrostis* spp. and other species adapted to a moist habitat (Table 2). The main clusters were located near the far right on the drier end of the axis and the remaining 35 percent of the plots were scattered along the X axis

Figure 4. Ordination of clusters from grove two, 1971.

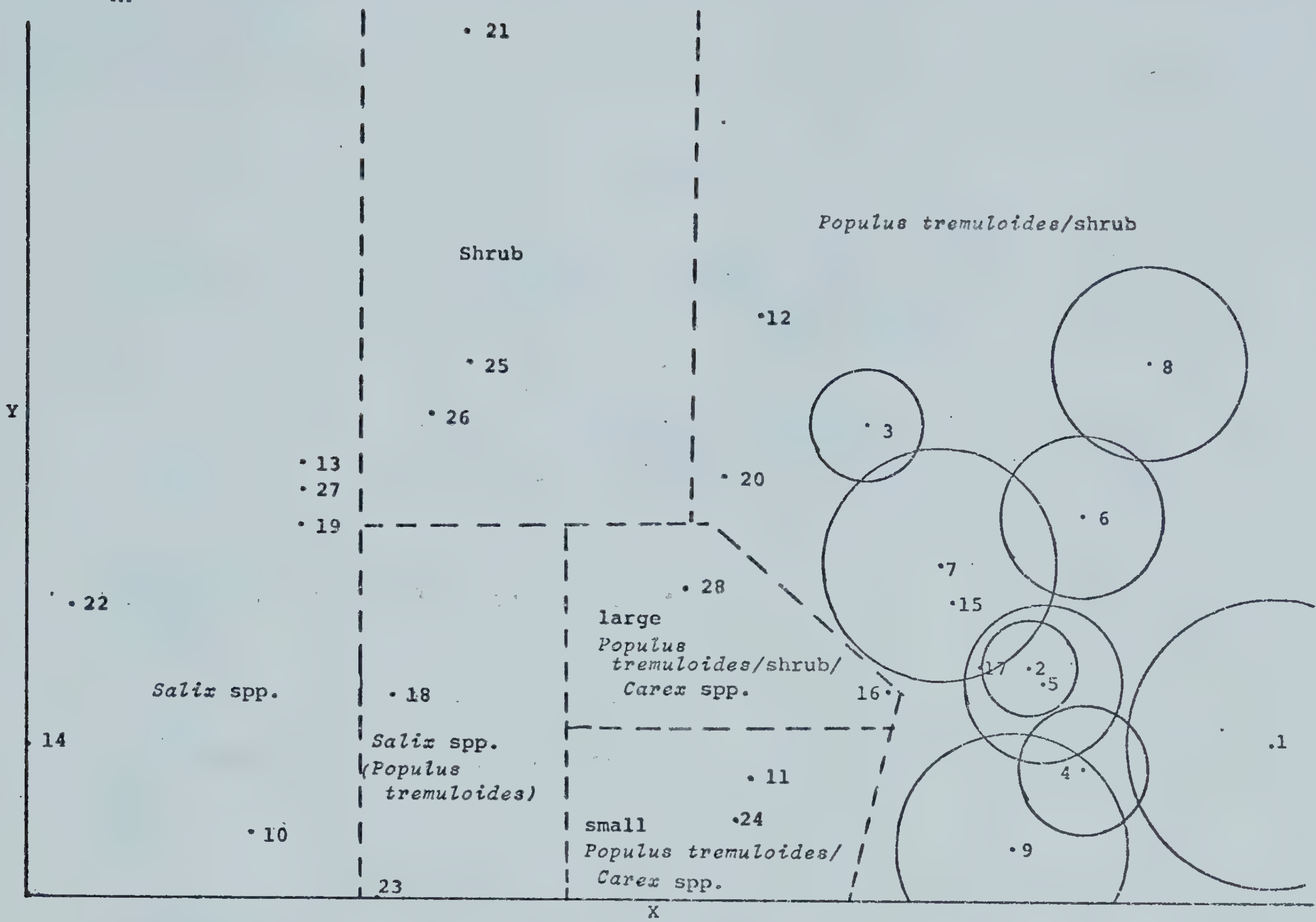
4A. on the XY plane

4B. on the XZ plane

Code	Cluster[a]
1	s, m *Populus tremuloides*
2	s *Populus tremuloides/Symphoricarpos occidentalis*
3	*Symphoricarpos occidentalis*
4	s, m *Populus tremuloides/Rosa woodsii*
5	m *Populus tremuloides*
6	m *Populus tremuloides/Symphoricarpos occidentalis*
7	m *Populus tremuloides/Amelanchier alnifolia*
8	m *Populus tremuloides/Rosa acicularis*
9	m *Populus tremuloides*
s	small *Populus tremuloides* 0 - 8.9 cm DBH
m	medium *Populus tremuloides* 8.9 = 17.8 cm DBH

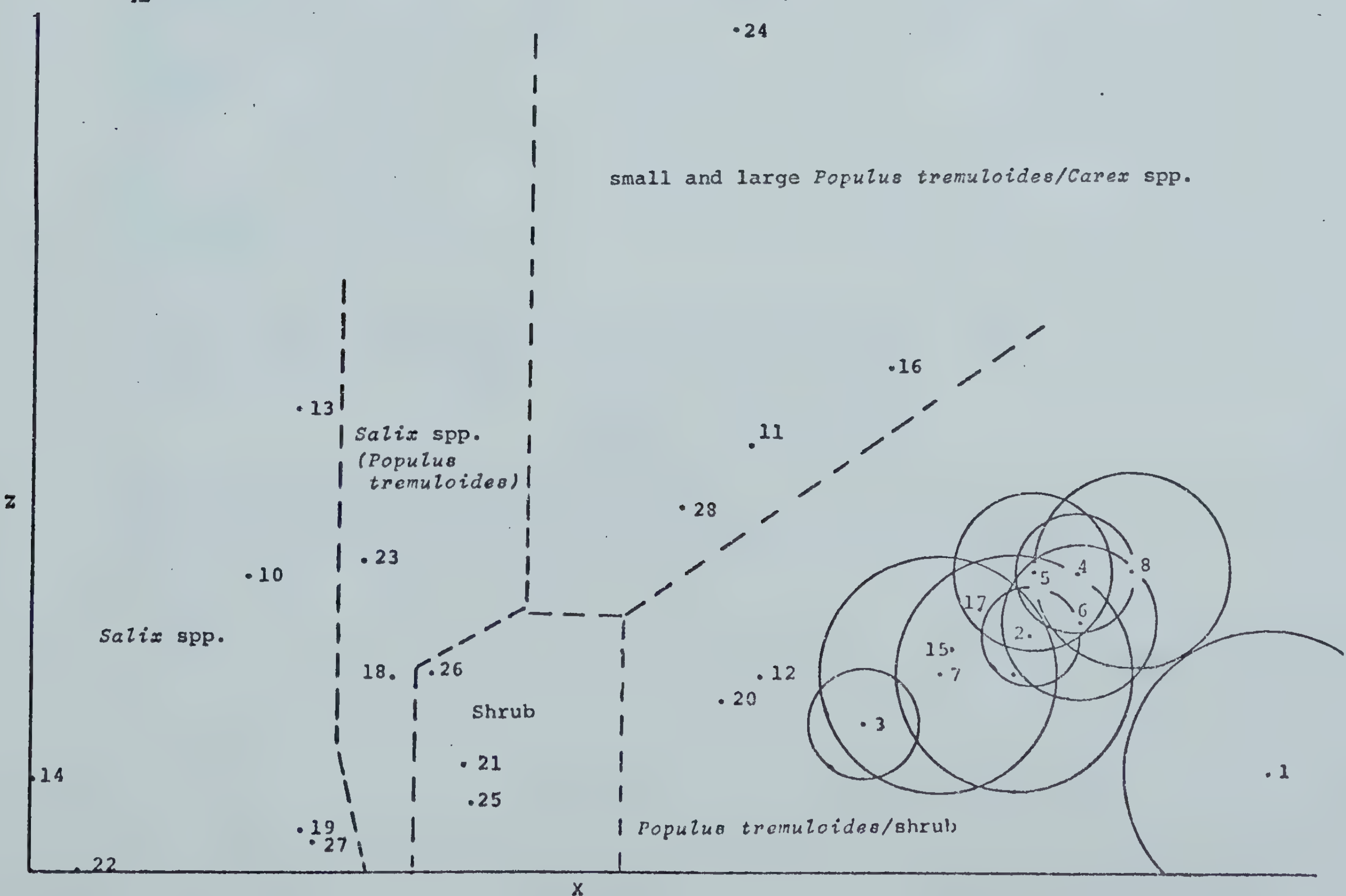
[a]Only the replicated clusters are named

4A



21
Shrub
Populus tremuloides/shrub
12
25
8
Y
26
3
13
27
20
6
19
7
22
28
large
Populus tremuloides/shrub/ Carex spp.
15
Salix spp.
18
16
17
2
5
14
Salix spp. (Populus tremuloides)
1
11
4
24
10
small Populus tremuloides/ Carex spp.
9
23
X

4B



24
small and large Populus tremuloides/Carex spp.
16
13
11
Salix spp. (Populus tremuloides)
Z
28
23
5
4
8
10
17
6
Salix spp.
2
15
18
26
12
7
20
Shrub
3
21
14
1
25
19
Populus tremuloides/shrub
27
22
X

TABLE 2

Mean Cover Values (%) of Important Species for Nine Main Clusters of Grove Two, 1971

Species	Code	Cluster Number[a]								
		1	8	6	4	5	2	9	7	3
		Cluster								
		s,m *Potr*[b]	m *Potr*/ *Roac*	m *Potr*/ *Syoc*	s,m *Potr* /*Rowo*	m *Potr*	s *Potr*/ *Syoc*	m *Potr*/	m *Potr*/ *Amal*	*Syoc*
		No. Quadrats								
		10	2	2	2	3	2	3	3	2
Amelanchier alnifolia	*Amal*	1		2		2		1	45	1
Smilacina stellata	*Smst*	3	7	1				2	2	5
Thalictrum venulosum	*Thve*	4	1	12	2				3	
Fragaria virginiana	*Frvi*	1		1		7	12			
Rosa acicularis	*Roac*	6	54	22	1	8				2
Rosa woodsii	*Rowo*	11	5	2	46	4		30	7	11
Populus tremuloides	*Potr*	97	92	89	98	96	90	96	74	
Symphoricarpos occidentalis	*Syoc*	31	8	39	25	1	45	14	24	22
Rubus strigosus	*Rust*	5	24	3	2	17	12	18	1	1
Calamagrostis spp.[c]	*Cal* spp.	1	4	6	1	6	2		3	4
Poa palustris	*Poapa*	1	4	1		7	1	3		12
Carex spp.[d]	*Carex*		3	1	8					2
Salix spp.[e]	*Salix*					4		9		

[a] Clusters in horizontal sequence as found on X axis from right to left

[b] *Populus tremuloides* size class: s - small 0 - 8.9 cm DBH
m - medium 9.0 - 17.8 cm DBH
l - large > 17.8 cm DBH

[c] Includes *Calamagrostis neglecta; C. inexpansa*

[d] Includes *Carex prairea* and small amounts of less common *Carex* species.

[e] Includes *Salix bebbiana; S. discolor*

further left (Figure 4).

Clusters were separated along the X axis on the basis of cover of *Salix* spp. and *Populus tremuloides*, and along the Y axis by their increasing abundance of *Populus tremuloides* or *Salix* spp. Those clusters (24, 16, 11 and 28) in which *Carex* spp. were dominant in the understory showed greater distance from the main clusters on the XZ ordination plane.

2. Grove Three

Cluster analysis of grove three yielded seven main clusters and nine single plot clusters (Figure 5). *Populus tremuloides* was the dominant tree in four clusters (1, 3, 6, and 7). These clusters were separated from one another by understory species and to a lesser degree by the actual cover values of *Populus tremuloides* (Table 3).

The X axis separated those clusters dominated by *Populus tremuloides* from those dominated by *Salix* spp. (clusters 2 and 8).

The Y axis seemed to separate those clusters (5 and 15), with higher *Rubus strigosus* cover and low *Populus tremuloides* from the remaining clusters. On the Z axis it was the clusters of lower *Populus tremuloides* cover and those with higher cover of understory grasses that were located farthest from the X axis (clusters 4, 10, 11, 13, 14 and 15).

Figure 5. Ordination of clusters from grove three, 1971.

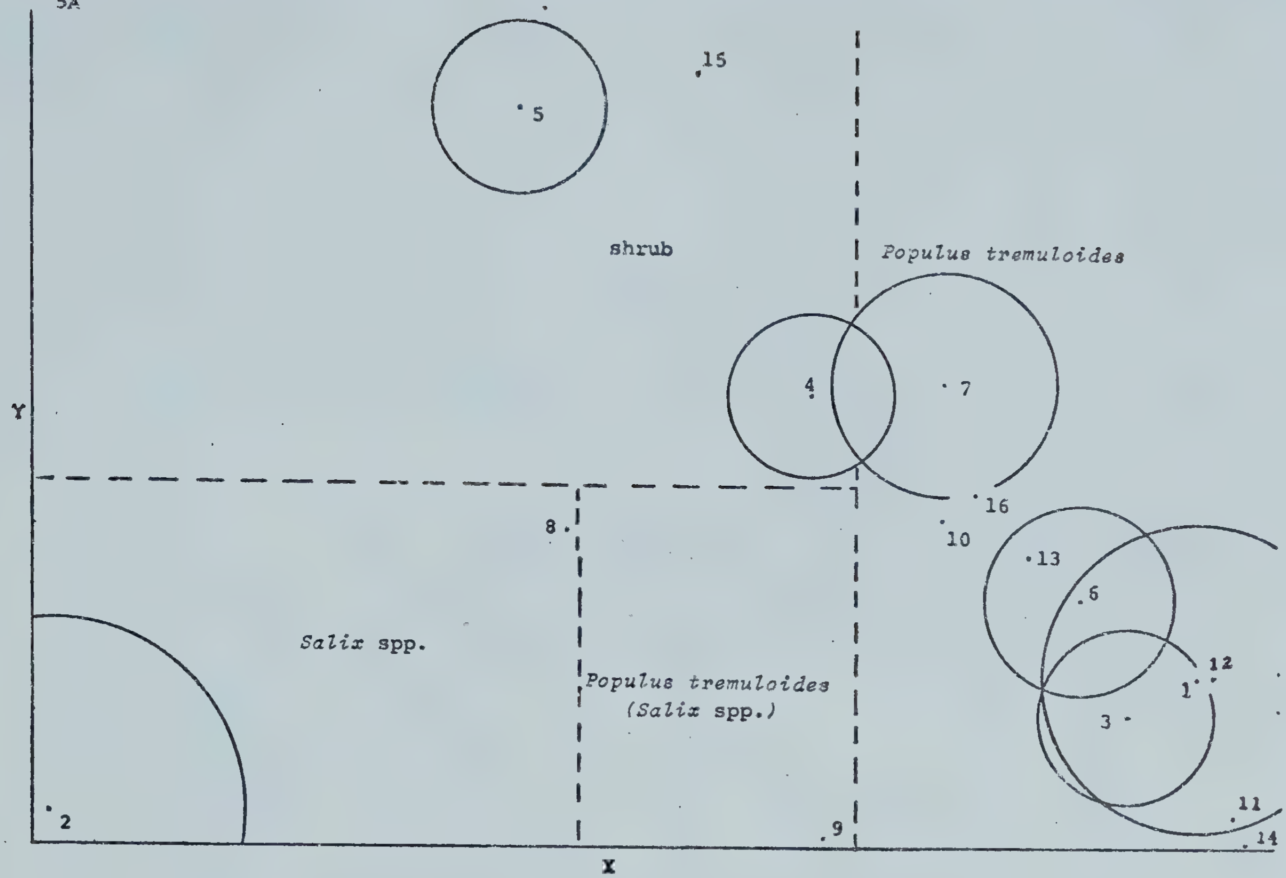
5A. on the XY plane

5B. on the XZ plane

Code	Cluster[a]
1	s, m *Populus tremuloides*
2	*Salix* spp.
3	l *Populus tremuloides/Carex* spp.
4	*Symphoricarpos occidentalis*
5	*Rubus strigosus/Poa palustris*
6	m, l *Populus tremuloides*
7	s *Populus tremuloides*
s	small *Populus tremuloides* 0 - 8.9 cm DBH
m	medium *Populus tremuloides* 9.0 - 17.8 cm DBH
l	large *Populus tremuloides* 17.8 cm DBH

[a]Only the replicated clusters (circles) are named

5A


15
5
shrub
Populus tremuloides
4
7
16
8
10
13
6
Salix spp.
Populus tremuloides
(Salix spp.)
12
1
3
11
2
9
14
Y
X

5B

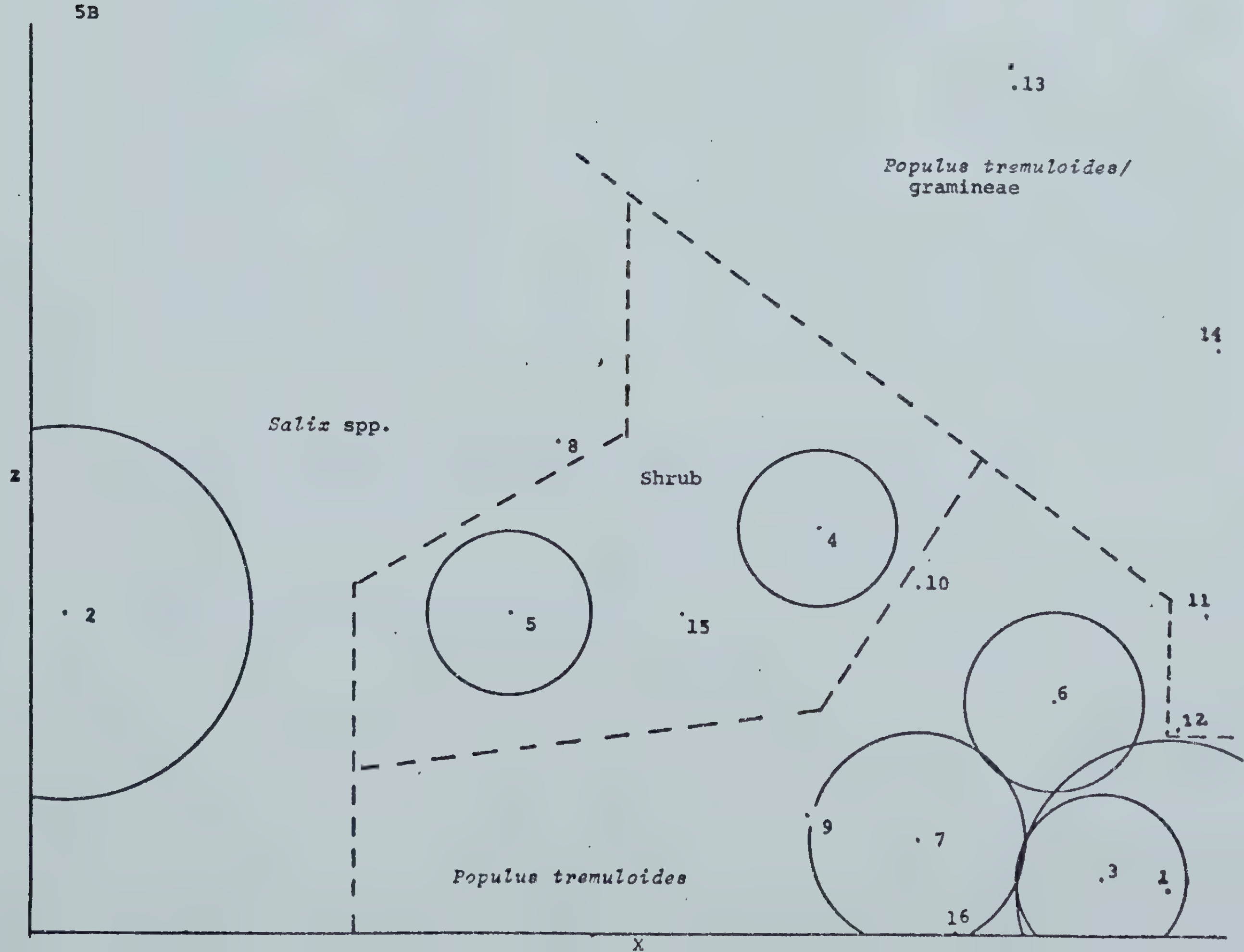

13
Populus tremuloides/
gramineae
14
Salix spp.
8
Shrub
Z
4
10
11
2
5
15
6
12
9
7
3
1
Populus tremuloides
16
X

TABLE 3

Mean Cover Values (%) of Important Species for Seven Main Clusters of Grove Three , 1971

Species	Code	Cluster Number[a] 1	3	6	7	4	5	2
		Cluster						
		s,m *Potr*[b]	*Potr/ Carex*	m,l *Potr*	s *Potr*	*Syoc*	*Rust/ Poapa*	*Salix* spp.
		No. Quadrats						
		18	4	2	3	2	2	8
Agropyron spp.	*Ag* spp.	5	1	1		4		
Festuca scabrella	*Fesc*	1	6	19	5			
Fragaria virginiana	*Frvi*	2	1	1	8	1		
Rosa acicularis	*Roac*	10	1	1	1	23		
Populus tremuloides	*Potr*	93	95	81	59	14		2
Symphoricarpos occidentalis	*Syoc*	24	9	19	8	59		1
Rubus strigosus	*Rust*	3	14	4	36		47	7
Carex spp.[c]	*Carex*	11	71	11	35		19	32
Anemone canadensis	*Anca*	1	2	4	8		7	4
Salix spp.[d]	*Salix*		1	4	6		24	96
Poa palustris	*Poapa*			8	12		68	28
Carex atherodes	*Caath*						6	4

[a]Clusters in horizontal sequence as found from right to left on X axis

[b]*Populus tremuloides* size classes s - small 0 - 8.9 cm DBH
m - medium 9.0 - 17.8 cm DBH
l - large > 17.8 cm DBH

[c]Mostly *Carex prairea*

[d]Includes *Salix bebbiana, S. discolor*

3. Grove Four

Four main clusters were separated leaving sixteen plots as single plot clusters (Figure 6). The four main clusters differed chiefly in cover of *Populus tremuloides*, *Salix* spp., *Rubus strigosus*, *Symphoricarpos occidentalis* and *Carex* spp. (Table 4). The clusters were distributed along the X axis from left to right in order of decreasing *Salix* spp. cover and increasing cover of *Populus tremuloides*. The mid-locations were once again taken up by clusters dominated by shrubs alone or in conjunction with *Populus tremuloides* with low cover values.

The Y axis seemed to separate clusters having a more dense herbaceous understory (clusters 5, 6, 16 and 17) from those with a more dominant shrub strata (Appendix 7). The *Populus tremuloides/Festuca scabrella* clusters (5 and 6) were located furthest along the Y axis from the X axis.

The majority of clusters were separated on the XY plane, but the shrub dominated and/or the low poplar cover clusters (6, 8, 9, 12, 13 and 20) and the *Populus tremuloides*/shrub/herb clusters (2 and 19) were differentiated on the XZ plane.

Although the vegetative picture using the four main clusters appeared most discontinuous, ecotones did exist as single plot clusters.

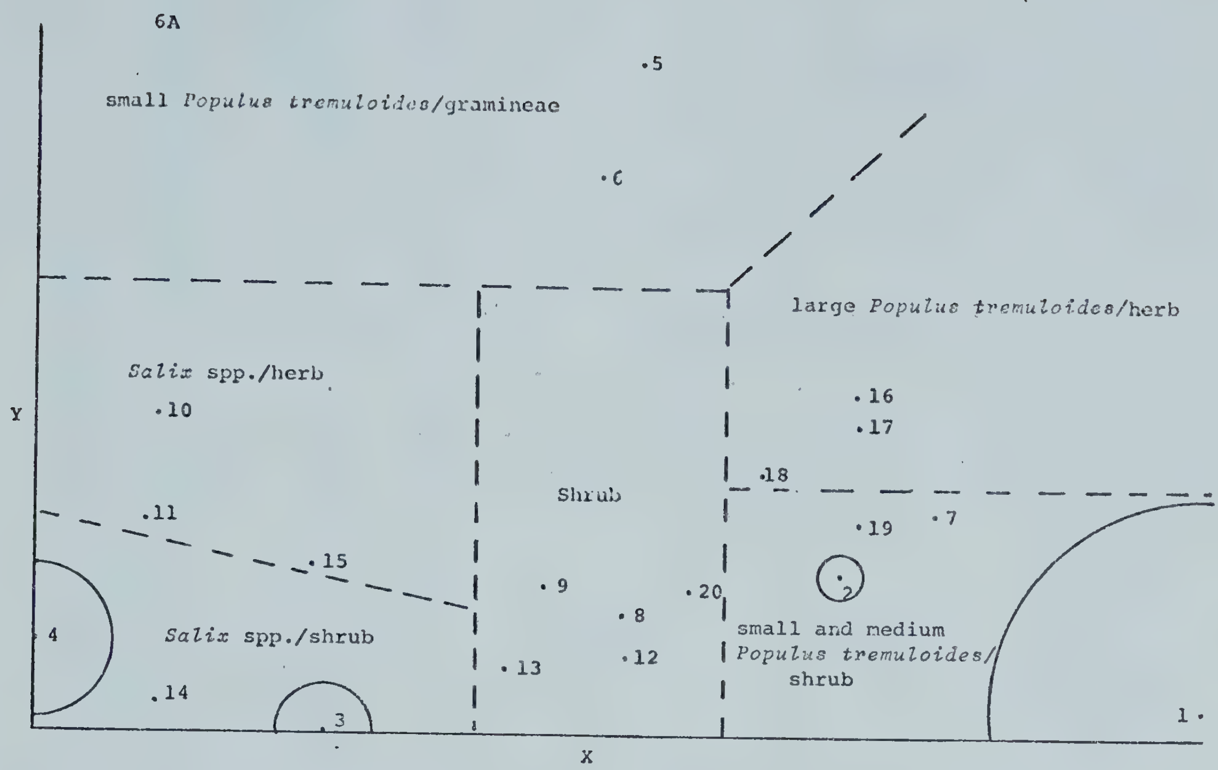
Figure 6. Ordination of clusters from grove four, 1971.

6A. on the XY plane

6B. on the XZ plane

Code	Cluster[a]
1	s, m *Populus tremuloides*
2	s *Populus tremuloides/Symphoricarpos occidentalis/Carex* spp.
3	*Salix* spp.
4	*Salix/Rubus strigosus/Carex* spp.
s	small *Populus tremuloides* 0 - 8.9 cm DBH
m	medium *Populus tremuloides* 9.0 - 17.8 cm DBH
l	large *Populus tremuloides* greater than 17.8 cm DBH

[a]Only the replicated clusters (circles) are named


6A
.5
small Populus tremuloides/gramineae
.6
large Populus tremuloides/herb
Salix spp./herb
Y
.10
.16
.17
.18
Shrub
.11
.19
.7
.15
.9
.20
2
4
Salix spp./shrub
.8
small and medium
Populus tremuloides/
shrub
.13
.12
.14
3
1
X

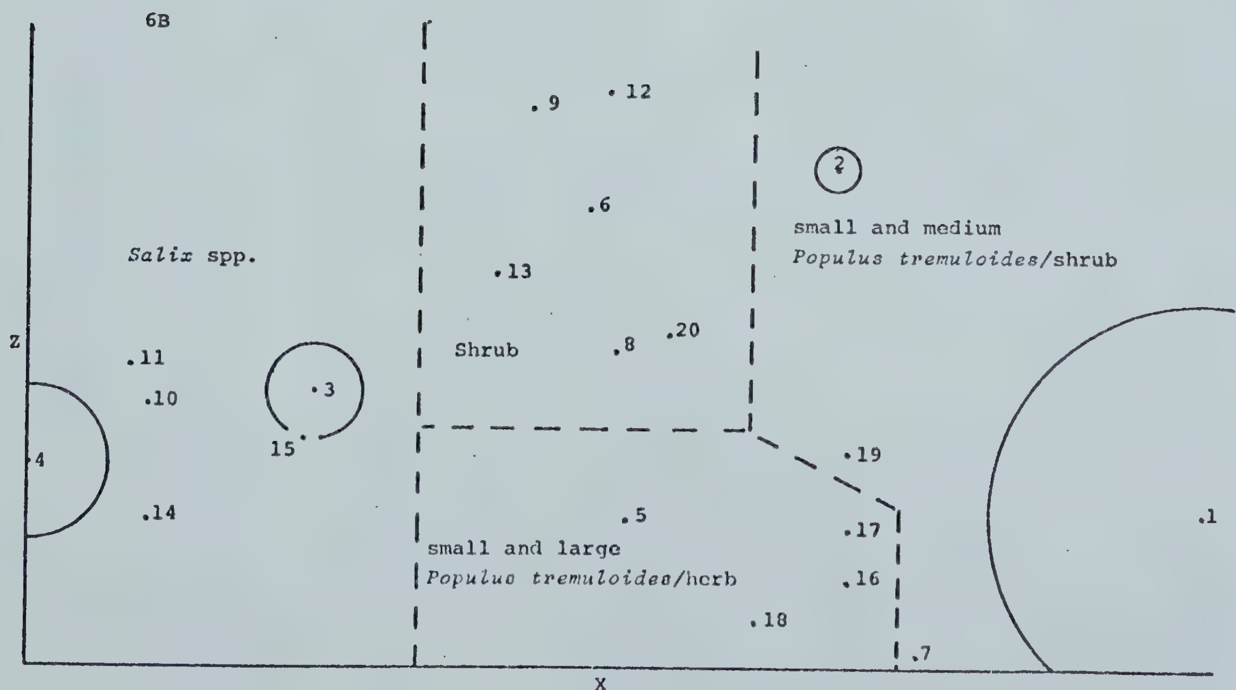

6B
.9
.12
2
.6
small and medium
Populus tremuloides/shrub
Salix spp.
.13
.20
Z
Shrub
.8
.11
.3
.10
15
.19
4
.14
.5
.1
.17
small and large
Populus tremuloides/herb
.16
.18
.7
X

TABLE 4

Mean Cover Values (%) of Important Species for the Four Main Clusters of Grove Four, 1971.

Cluster Number[a]		1	2	3	4
Cluster		s,m *Potr*[b]	s *Potr/ Syoc/Carex*	*Salix* spp.	*Salix/ Rust/Carex*
No. of Quadrats		26	2	2	2
Species	Code				
Rosa woodsii	*Rowo*	5	23		
Populus tremuloides	*Potr*	94	72		
Smilacina stellata	*Smst*	1		6	
Amelanchier alnifolia	*Amal*	2		19	
Rosa acicularis	*Roac*	7	2	1	
Symphoricarpos occidentalis	*Syoc*	37	68	23	2
Carex spp.[c]	*Carex*	10	71	3	56
Rubus strigosus	*Rust*	3		1	46
Salix spp.[d]	*Salix*			98	96

[a]Clusters in horizontal order as found on X axis from right to left

[b]*Populus tremuloides* size classes: s - small 0 - 8.9 cm DBH; m - medium 9.0-17.8 cm DBH

[c]Mostly *Carex prairea*

[d]Includes *Salix bebbiana; S. discolor*

4. Grove Five

Eight main clusters were recognized leaving nine single plot clusters (Figure 7). There were three main separations evident in the ordination, one corresponding to each axis. Along the X axis *Populus tremuloides* dominated clusters (Table 5, Appendix 8) were separated from clusters of *Populus balsamifera* and *Salix* spp. dominance.

The Y axis separated these *Populus tremuloides*/*Carex* spp. clusters (8, 14 and 12) from *Populus tremuloides*/shrub, *Salix* spp. and *Populus balsamifera* clusters (Figure 7). The *Populus tremuloides*/herb clusters (9 and 10) were centrally located between the latter three cluster types in the XY plane. The cover values of *Populus tremuloides* also increased from bottom to top of the Y axis.

The *Salix* spp. cluster (3) was lifted above the XY plane and separated on the Z axis from the other moist habitat clusters dominated by *Populus balsamifera*.

For grove five there appeared to be four main groups of clusters with only a limited amount of continuity among them. These were the *Populus tremuloides*/shrub, the *Populus tremuloides*/*Carex* spp., the *Salix* spp. and the *Populus balsamifera* group of clusters. The *Populus tremuloides*/herb clusters acted as the continuity between *Populus*/shrub and*Populus*/*Carex* spp. clusters but there

Figure 7. Ordination of the clusters from grove five, 1971.

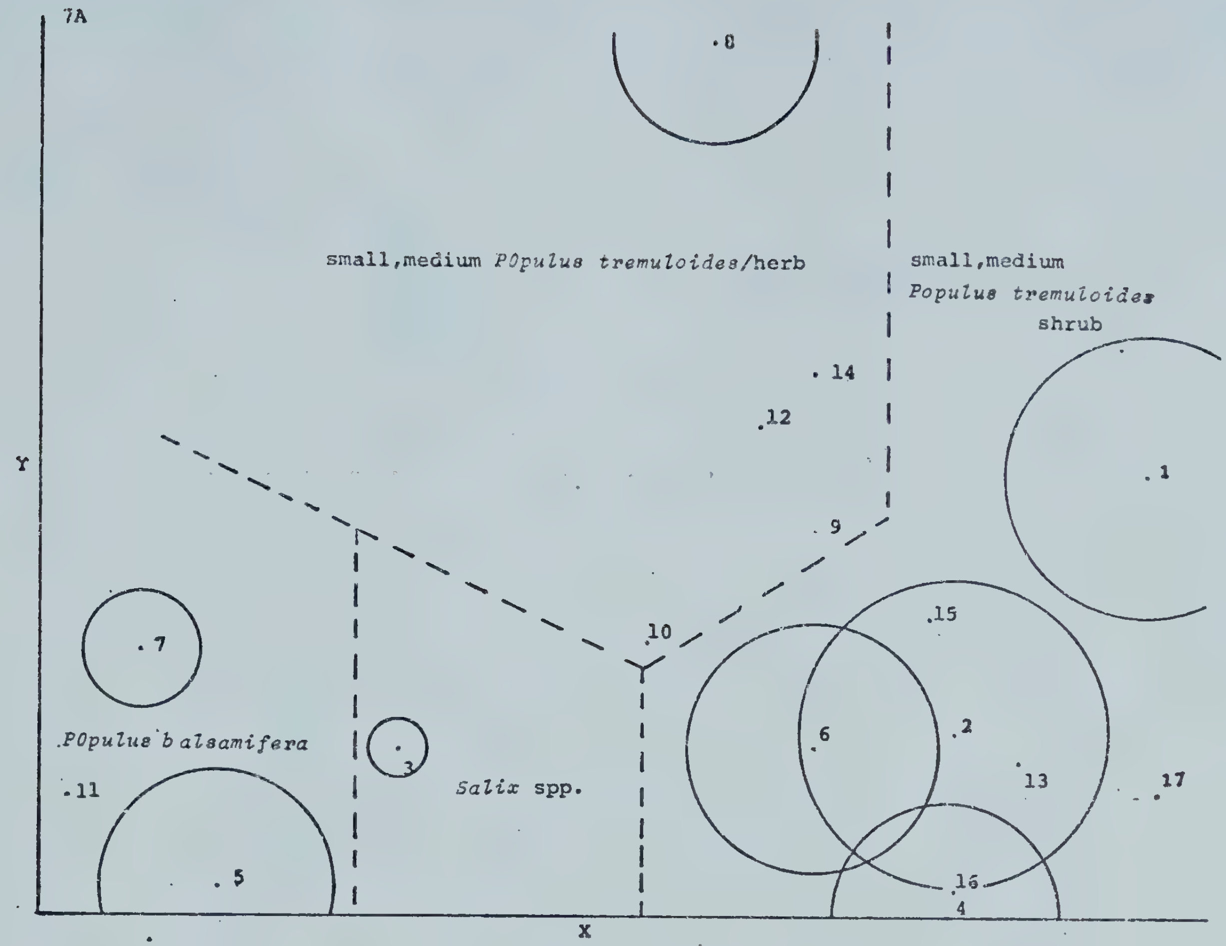
7A. on the XY plane

7B. on the XZ plane

Code	Cluster[a]
1	s, m *Populus tremuloides/Symphoricarpos occidentalis*
2	s, m *Populus tremuloides/Amelanchier alnifolia*
3	*Salix/Calamagrostis* spp.
4	*Symphoricarpos occidentalis*
5	*Populus balsamifera*
6	m *Populus tremuloides*
7	*Populus balsamifera/Carex* spp. - *Carex atherodes*
8	s, m *Populus tremuloides/Carex*
s	small *Populus tremuloides* 0 - 8.9 cm DBH
m	medium *Populus tremuloides* 9.0 - 17.8 cm
l	large *Populus tremuloides* greater than 17.8 cm DBH

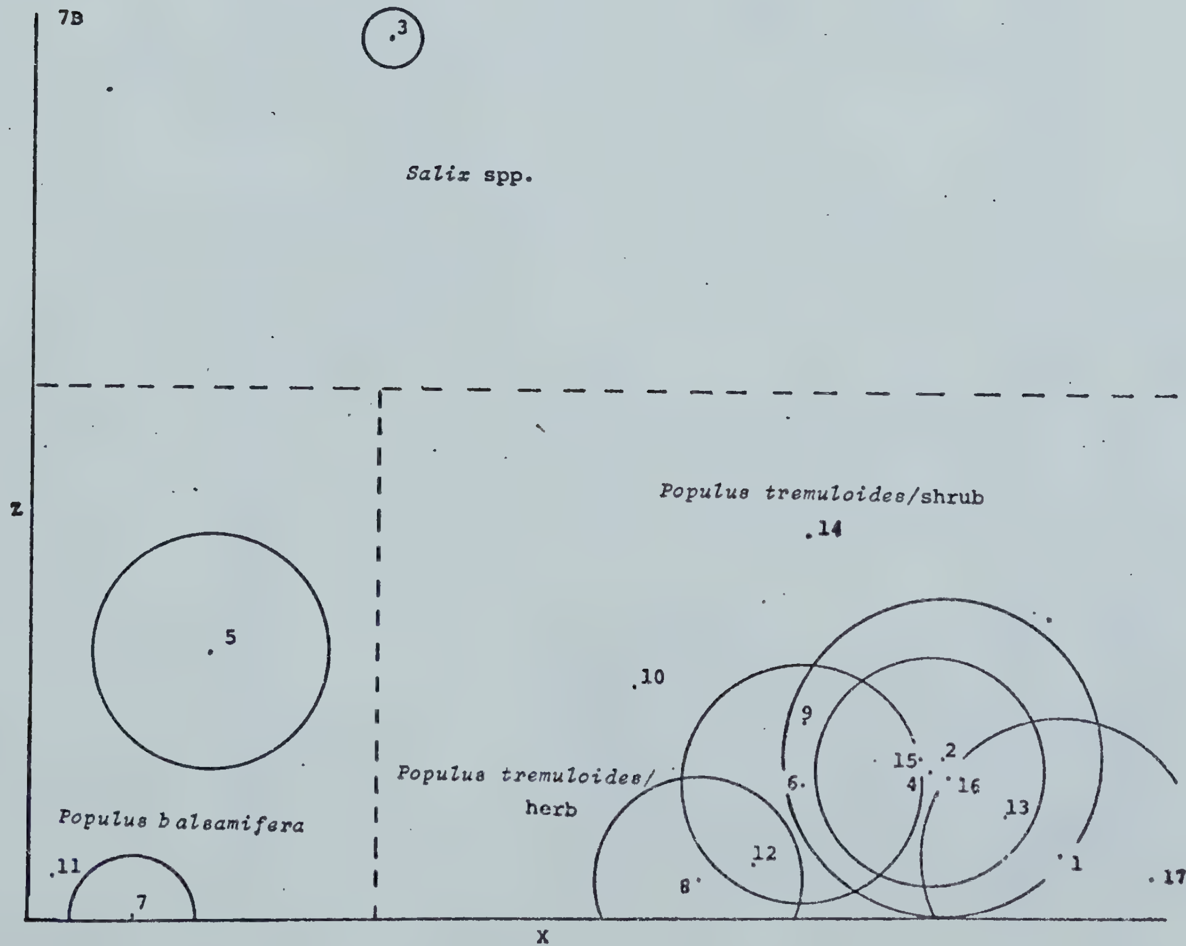
[a]Only the replicated clusters are named

7A



8
small,medium *POpulus tremuloides*/herb
small,medium
Populus tremuloides
shrub
14
12
Y
1
9
15
7
10
POpulus balsamifera
6
2
3
Salix spp.
11
13
17
5
16
4
X

7B



3
Salix spp.
Populus tremuloides/shrub
Z
14
5
10
9
15
2
Populus tremuloides/
herb
6
4
16
13
Populus balsamifera
12
11
1
17
8
7
X

TABLE 5

Mean Cover Values (%) of Important Species for the Eight Main Clusters of Grove Five , 1971

Species	Code	Cluster Number[a]							
		1	2	4	6	8	3	5	7
		Cluster							
		s,m Potr/ Syoc	*s,m Potr/ Amal*	*Syoc*	*m Potr*	*s,m Potr/ Carex*	*Salix/ Cal spp.*	*Poba*	*Poba/Carex spp. Caath*
		Number Quadrats							
		10	10	4	4	2	2	5	2
Festuca scabrella	*Fesc*			9				15	
Amelanchier alnifolia	*Amal*	1	81					3	
Rosa acicularis	*Roac*	10	3	6	10	95		3	
Populus tremuloides[b]	*Potr*	96	81		60	1		6	
Symphoricarpos occidentalis	*Syoc*	41	13	72	24		2		
Rubus strigosus	*Rust*	6		4	2	64	4	5	71
Carex spp.[c]	*Carex*	8		5	1	1	94	21	
Populus balsamifera	*Poba*	1				12		80	82
Salix spp.[d]	*Salix*		7	22		22	54	1	8
Calamagrostis spp.[e]	*Cal* spp.			1		11	1	5	50
Carex atherodes	*Caath*					4	4		14
Poa palustris	*Poapa*								

[a]Clusters in horizontal sequence as arranged from right to left on X axis

[b]*Populus tremuloides* size class: s - small 0 - 8.9 cm DBH; m - medium 9.0 - 17.8 cm DBH; l - large 17.8 cm DBH

[c]Mostly *Carex prairea*

[d]Includes *Salix bebbiana; S. discolor*

[e]Includes *Calamagrostis neglecta; C. inexpansa*

was little continuity evident among the latter groups and the *Salix* spp. or *Populus balsamifera* clusters.

5. Grove Eight

Four major clusters and fifteen single plot clusters were recognized (Figure 8). Once again *Populus tremuloides* and *Salix* spp. dominated clusters (Table 6) were separated along the X axis, with clusters of predominantly shrub overstory (clusters 2, 7, 8, 10 and 19) located near center.

The Y axis was related to increasing cover of shrubs and decreasing cover of *Populus tremuloides* (Appendix 9).

Separation of clusters along the Z axis appeared to be from high herbaceous cover near the X axis (clusters 17 and 18) to low herbaceous cover (clusters 1 and 13). The Z axis actually lifted most of the clusters about equally above the X axis (XY plane) with the *Populus tremuloides*/shrub group located furthest up the Z axis. It would seem therefore that in grove eight the herbaceous understory did not differ greatly among the majority of clusters. A discontinuity between *Salix* spp. dominated clusters and the remaining clusters existed in grove eight. The remaining clusters, however, formed a continuum from high to low *Populus* cover along the X axis.

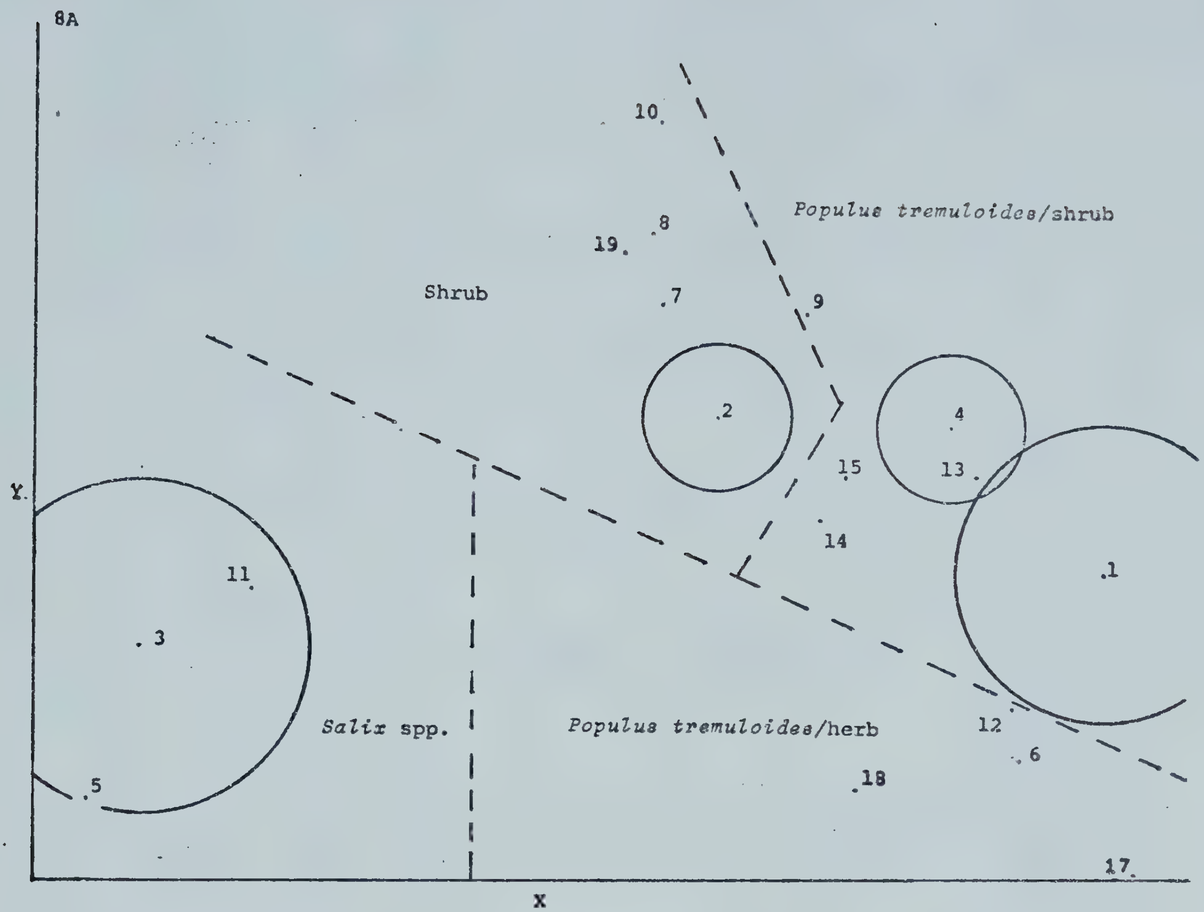
Figure 8. Ordination of the clusters from grove eight, 1971.

8A. on the XY plane

8B. on the XZ plane

Code	Cluster[a]
1	s, m *Populus tremuloides*
2	*Rosa acicularis*
3	*Salix* spp.
4	s, m *Populus tremuloides*/*Symphoricarpos occidentalis*
s	small *Populus tremuloides* 0 - 8.9 cm DBH
m	medium *Populus tremuloides* 9.0 - 17.8 cm DBH

[a]Only the replicated clusters are named.


8A
10
Populus tremuloides/shrub
8
19
Shrub
7
9
2
4
15
13
Y
14
1
11
3
Salix spp.
Populus tremuloides/herb
12
6
5
18
17
X

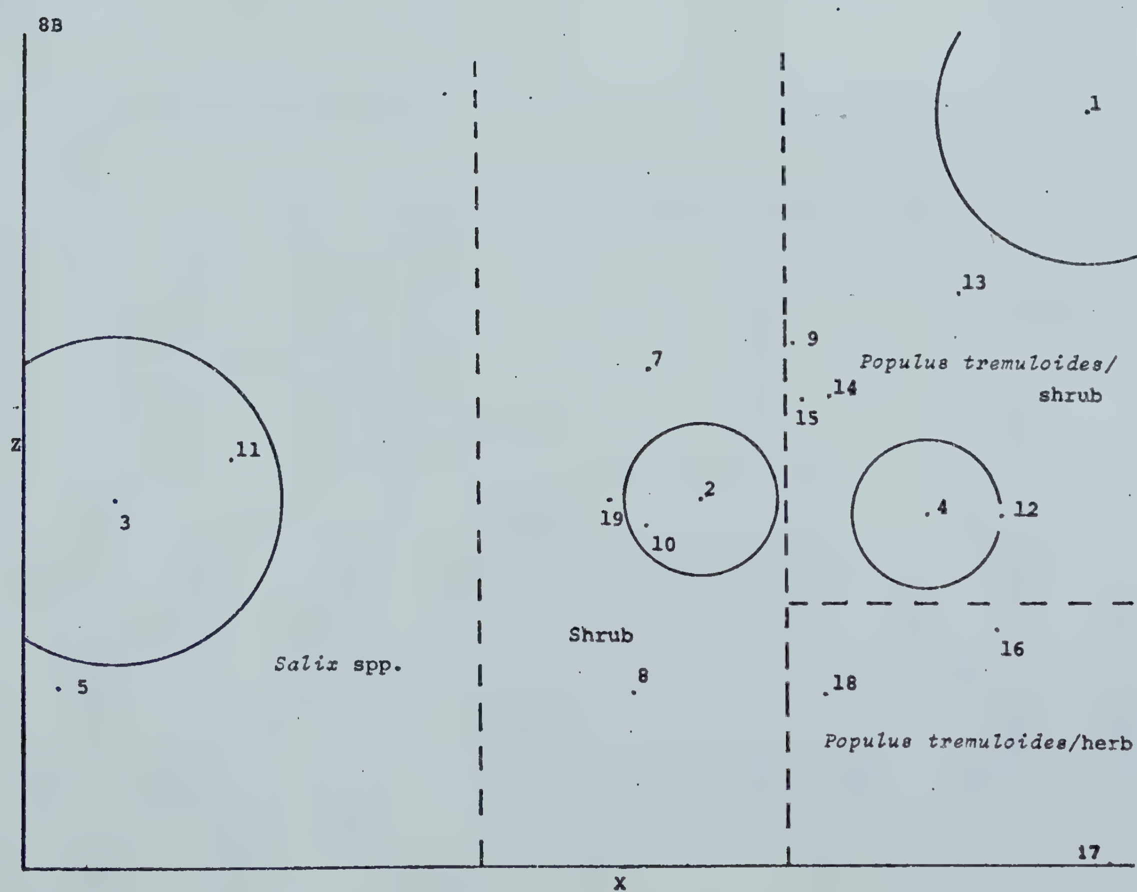

8B
1
13
9
7
Populus tremuloides/
shrub
14
15
Z
11
2
4
12
19
3
10
16
Shrub
Salix spp.
5
8
18
Populus tremuloides/herb
17
X

TABLE 6

Mean Cover Values (%) of Important Species for the Four Main Clusters of Grove Eight, 1971

Cluster Number[a]		1	4	2	3
Cluster		s,m *Potr*[b]	s,m *Potr/Syoc*	*Roac*	*Salix* spp.
No. of Quadrats		15	2	4	12
Species	Code				
Amelanchier alnifolia	*Amal*	13	1		
Fragaria virginiana	*Frvi*	2	11	8	
Rosa acicularis	*Roac*	16		14	8
Ribes oxyacanthoides	*Riox*	1		8	2
Populus tremuloides	*Potr*	<u>82</u>	<u>55</u>	6	
Symphoricarpos occidentalis	*Syoc*	28	<u>70</u>	7	5
Taraxacum officinale	*Taof*	1	4	4	1
Carex spp.[c]	*Carex*	4	32	1	15
Poa palustris	*Poapa*	1		1	10
Salix spp.[d]	*Salix*				<u>78</u>

[a]Clusters in horizontal sequence as arranged left to right on the X axis

[b]*Populus* size class: s - small 0 - 8.9 cm DBH; m - medium 9.0 - 17.8 cm DBH

[c]Mostly *Carex prairea*

[d]Includes *Salix bebbiana; S. discolor*

6. Grove Ten

Of the six major clusters, four were dominated by *Populus tremuloides* (Table 7) and were located to the right end of the X axis (Figure 9) while the *Salix* spp. dominated clusters were located at the far left. Intermediary positions along the X axis were occupied by the *Salix-Populus tremuloides* cluster (16) and those clusters with little or no *Populus tremuloides* (Appendix 10 and/or with a dominant shrub (clusters 11, 13, 14 and 15).

The Y axis served to separate cluster 2 and to a lesser degree, cluster 5 from the remaining clusters. The common component of clusters 2 and 5 was the presence of *Carex atherodes*, *Calamagrostis* spp., *Poa palustris* and *Salix* spp.

The Z axis drew those clusters with shrub dominant and/or low *Populus tremuloides* cover away from the XY plane. However, the cover values were such that a continuum actually existed between the shrub clusters and the *Salix* clusters in one direction and the shrub clusters and the *Populus tremuloides*/shrub clusters in the other direction.

7. Groves Two, Three, Four and Ten

Cluster analysis of plots in groves two, three, four and ten resulted in forty-two main clusters and thirty-nine single plot clusters. However, there were only sixteen main clusters that were not linked to any other

TABLE 7

Mean Cover Values (%) of Important Species for the Six Main Clusters of Grove Ten , 1971

Cluster No.[a]		1	6	2	5	4	3
Cluster		s,m,l *Potr*[b]	m *Potr/Roac*	s *Potr/Caath*	s,m *Potr/Rust*	*Salix* spp.	*Salix* spp.
No. Quadrats		23	2	2	4	4	3
Species	Code						
Amelanchier alnifolia	*Amal*		11				
Ribes oxyacanthoides	*Riox*	2					
Rosa acicularis	*Roac*	8	52	1		7	7
Rosa woodsii	*Rowo*	8			1	5	6
Populus tremuloides	*Potr*	88	87	98	82	1	
Symphoricarpos occidentalis	*Syoc*	34	6		6	5	3
Anemone canadensis	*Anca*	3	2	1	8	2	2
Arenaria lateriflora	*Arla*	1	6	1	1	1	1
Rubus strigosus	*Rust*	9	6	2	53	6	4
Carex spp.[c]	*Carex*	10	12	1	10	11	10
Calamagrostis spp.[d]	*Cal* spp.			6	1		
Poa palustris	*Poapa*			4	7	6	
Carex atherodes	*Caath*			79	12	10	
Salix spp.[e]	*Salix*			1	8	41	91

a Clusters in horizontal sequence as arranged from right to left on the x axis

b *Populus tremuloides* size class: s - small 0 - 8.9 cm DBH; m - medium 9.0 - 17.6 cm DBH; l - large > 17.8 cm DBH

c Mostly *Carex prairea*

d Includes *Calamagrostis neglecta; C. inexpansa*

e Includes *Salix bebbiana; S. discolor*

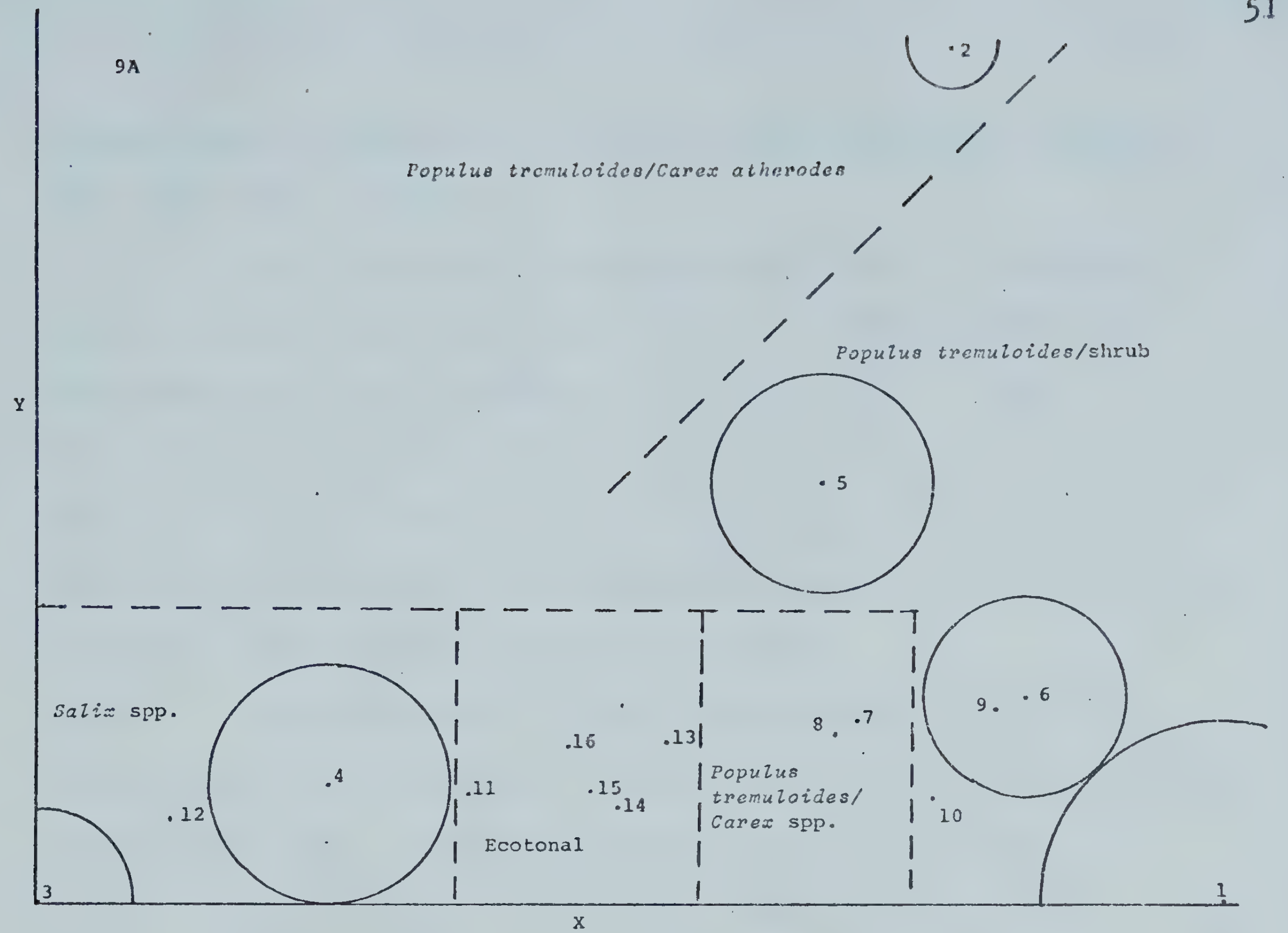
Figure 9. Ordination of the clusters from grove ten, 1971.

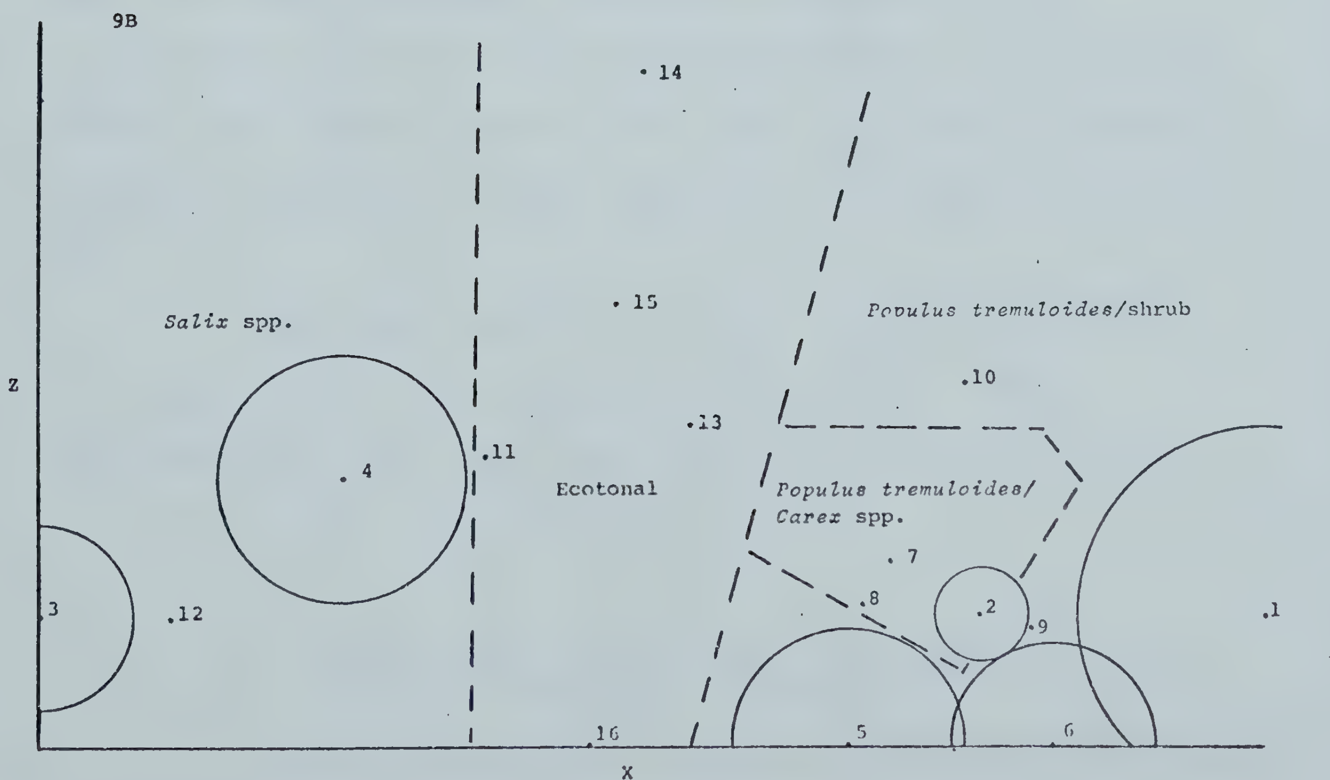
9A. on the XY plane

9B. on the XZ plane

Code	Cluster[a]
1	s, m, l *Populus tremuloides*
2	s *Populus tremuloides/Carex atherodes*
3	*Salix* spp.
4	*Salix* spp.
5	s, m *Populus tremuloides/Rubus strigosus*
6	m *Populus tremuloides/Rosa acicularis*
s	small *Populus tremuloides* 0 - 8.9 cm DBH
m	medium *Populus tremuloides* 8.9 - 17.8 cm DBH
l	large *Populus tremuloides* > 17.8 cm DBH

[a]Only the replicated clusters are named


9A
Populus tremuloides/Carex atherodes
Populus tremuloides/shrub
Y
Salix spp.
Populus tremuloides/
Carex spp.
Ecotonal
X
.2
.5
8
.7
9
.6
.16
.13
.4
.11
.15
.14
.12
.10
3
1


9B
.14
.15
Salix spp.
Populus tremuloides/shrub
.10
Z
.13
.11
.4
Ecotonal
Populus tremuloides/
Carex spp.
.7
.8
.2
.9
3
.12
.1
.16
5
6
X

cluster and of these less than half were comprised of more than two plots (Table 8).

The X axis was interpreted as one of increasing *Populus tremuloides* cover from left to right (Figure 10). The centrally located clusters had little or no cover of *Salix* spp. or *Populus tremuloides* (clusters 2, 9, 18, 27 and 41) or had a dominant shrub (clusters 30 and 40). The clusters represented a continuum of vegetation based on *Salix* spp. and *Populus tremuloides* cover.

Interpretation of the Y axis seemed to be that of a shrub cover gradient. However, distribution of clusters along the Y axis tended to be influenced by the cover of *Populus tremuloides* as well as the shrub species. The clusters having lower *Populus tremuloides* cover (18, 27 and 41) or an understory dominance of *Symphoricarpos occidentalis* (1, 2 and 25) were located above the clusters having high *Populus tremuloides* cover and greater abundance of *Rubus strigosus* or *Rosa acicularis* (clusters 11, 26 and 42).

The major separation on the Z axis was based on abundance of *Carex atherodes* in cluster 5. Very high cover of *Salix* spp. continued to separate clusters 4, 33 and 35 from the remaining clusters.

8. Groves Two, Three, Four, Five,Eight and Ten, *Populus tremuloides* Eliminated

All six groves were used in a cluster analysis and ordination where *Populus tremuloides* was excluded from

TABLE 8

Mean Cover Values (%) of Important Species for the Sixteen Non-linked Clusters of Groves 2, 3, 4 and 10, 1971.

Cluster Number[(a)]		11	1	26	25	42	2	5	41	27	18	40	30	9	33	4	35
Cluster		m *Potr*[(b)]/*Roac*	s m/*Potr/Syoc*	m *Potr*	s *Potr/Syoc*	m *Potr/Roac*	s *Potr/Syoc/Carex*	s *Potr/Caath*	m, l *Potr*	s *Potr*	*Syoc*	*Roac*	*Rust/Poapa*	*Salix*	*Salix/Carex*	*Salix*	*Salix/Rust/Carex*
No. Quadrats		3	37	3	2	2	2	2	2	4	4	2	2	8	2	11	2
Species	Code																
Thalictrum venulosum	*Thve*	1				16			4		2						
Lathyrus ochroleucus	*Laoc*	3		4	8	1	1		6								
Amelanchier alnifolia	*Amal*					24				1	2			5			
Populus tremuloides	*Potr*	94	94	97	90	84	76	98	48	60	6			1	8		
Symphoricarpos occidentalis	*Syoc*	13	42	2	52	8	68		23	18	13	4		9	4	4	2
Rosa acicularis	*Roac*	52	5	2		42	2	1	6	1	2	52		4	1	3	
Rosa woodsii	*Rowo*	3	4	22	17		23		3	3		2		2		2	
Rubus strigosus	*Rust*	5	2	20	5	11		2	14	33	4	2	47	6	2	7	46
Ribes oxyacanthoides	*Riox*	3		2		5			1	1	2	2		1		6	1
Carex spp.[(c)]	*Carex*		2		8	36	71	1	6	35	2	10	19	10	60	15	56
Anemone canadensis	*Anca*	2	1					1	1	6	4	1	6	2	4	3	
Salix spp.[(d)]	*Salix*			4				1	4	4	1	10	24	42	98	93	96
Poa palustris	*Poapa*							4		5	1		68	3	8	19	1
Carex atherodes	*Caath*							79					6	10	2	2	
Calamagrostis spp.[(e)]	*Cal* spp.							6		2			1	1			

[a] Clusters in horizontal sequence as arranged from right to left on x axis on Figure 10.

[b] *Populus tremuloides* size class: s - small 0 - 8.9 cm DBH; m - medium 9.0 - 17.8 cm DBH; l - large > 17.8 cm DBH

[c] Mostly *Carex prairea*

[d] Includes *Salix bebbiana; S. discolor*

[e] Includes *Calamagrostis neglecta; C. inexpansa*

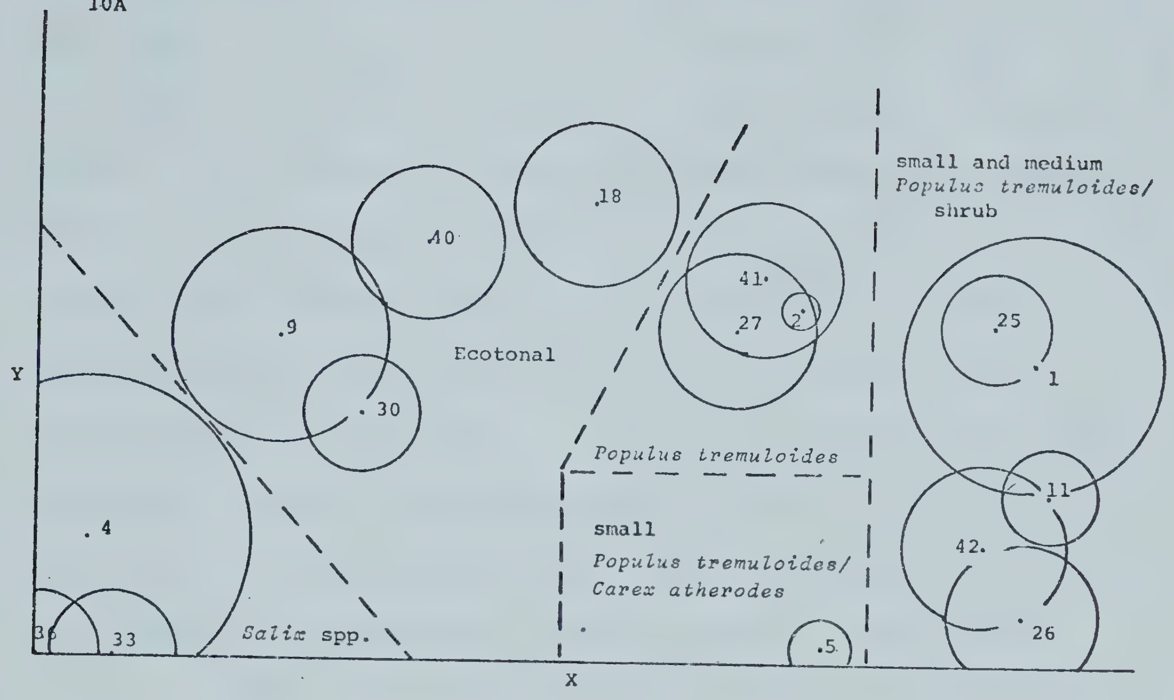
Figure 10. Ordination of the non-linked clusters from four groves, 1971.

10A. on the XY plane

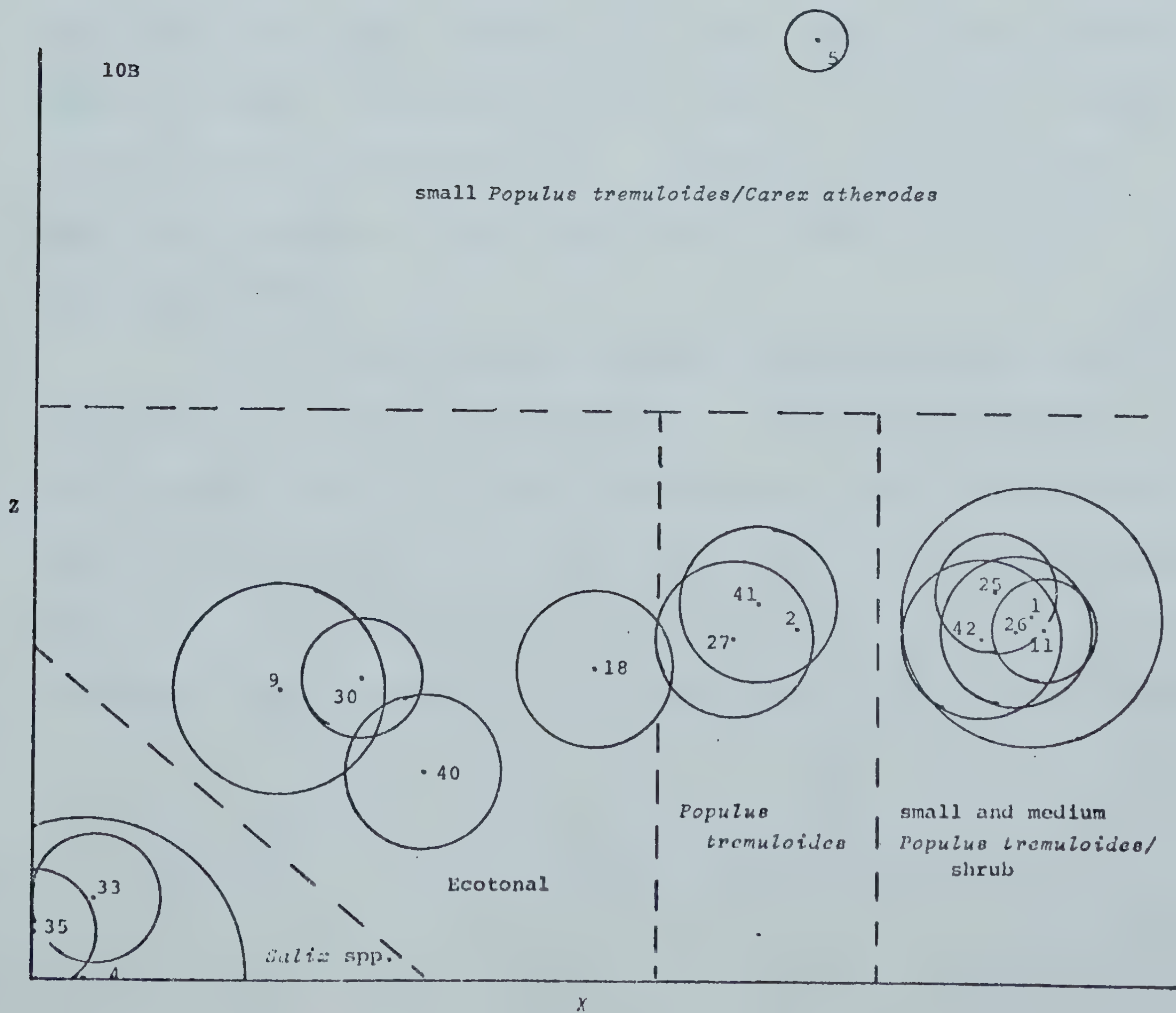
10B. on the XZ plane

Code	Cluster
1	s,m *Populus tremuloides/Symphoricarpos occidentalis*
2	s *Populus tremuloides/Symphoricarpos occidentalis/ Carex* spp.
4	*Salix* spp.
5	s *Populus tremuloides/Carex atherodes*
9	*Salix* spp.
11	m *Populus tremuloides/Rosa acicularis*
18	*Symphoricarpos occidentalis*
25	s *Populus tremuloides/Symphoricarpos occidentalis*
26	m *Populus tremuloides*
27	s *Populus tremuloides*
30	*Rubus strigosus/Poa palustris*
33	*Salix/Carex*
35	*Salix/Rubus strigosus/Carex* spp.
40	*Rosa acicularis*
41	m,l *Populus tremuloides*
42	m *Populus tremuloides/Rosa acicularis*
s	small *Populus tremuloides* 0 - 8.9 cm DBH
m	medium *Populus tremuloides* 8.9 - 17.8 cm DBH
l	large *Populus tremuloides* $>$ 17.8 cm DBH

10A


Y
X
18
40
9
30
4
36
33
41
27
2
25
1
11
42
26
5
Ecotonal
Salix spp.
Populus tremuloides
small
Populus tremuloides/
Carex atherodes
small and medium
Populus tremuloides/
shrub

10B


Z
X
5
small Populus tremuloides/Carex atherodes
9
30
40
18
41
2
27
25
1
42
26
11
33
35
4
Ecotonal
Salix spp.
Populus
tremuloides
small and medium
Populus tremuloides/
shrub

consideration. The *Salix* spp. dominated clusters (Table 9) remained at the left of the X axis while the canopy cover of understory shrubs increased to the right. Centrally located were those clusters with *Rubus strigosus* (44), *Carex prairea* and *Carex atherodes* (10 and 25), and *Populus balsamifera* (18 and 24) components, as well as those with low cover of *Salix* spp. or *Symphoricarpos occidentalis* (9, 23 and 40). That is, those plots least similar to either *Salix* cluster or *Symphoricarpos occidentalis* cluster were all located centrally though they were not necessarily similar one to the other.

The Y axis separated the *Populus balsamifera* from the *Salix* spp. (cluster 2). The Y axis also separated those clusters with abundant *Carex* spp. (25 and 44) and/or *Carex atherodes* (cluster 10). Clusters 2 and 40 would have been higher up the Y axis but for the cover of *Salix* spp. (Figure 11).

The Z axis was a gradient based on shrub cover. Cluster 1, with high *Symphoricarpos occidentalis* cover and clusters 38 and 44 with dominant *Rubus strigosus* were furthest away from the X axis while the *Populus balsamifera/ Carex* spp.-*Carex atherodes* (18) cluster and clusters of very low shrub cover (9, 23 and 40) were closest to the XY plane.

TABLE 9

Mean Cover Values (%) of Important Species for the Twelve Non-Linked Clusters of Six Groves, with the Exclusion of *Populus tremuloides*, 1971

Cluster No.		1	3	23	25	9	24	44	40	38	18	10	2
Cluster		*Syoc*	*Syoc/ Carex*	Ecotonal	*Carex* spp.	Ecotonal	*Poba*	*Rust / Carex*	*Salix/ Carex*	*Rust/ Poapa*	*Poba/Carex (Caath)*	*Salix / Caath*	*Salix*
No. Quadrats		33	5	4	3	3	4	3	3	2	2	3	15
Species	Code												
Rosa woodsii	*Rowo*	2	21								1		
Amelanchier alnifolia	*Amal*	4	3						1				
Aster laevis	*Asla*				3	9							
Agropyron spp.	*Ag* spp.	1	2	1	17	2			1		1		
Symphoricarpos occidentalis	*Syoc*	41	59	8	9	16	4	4	14				1
Rosa acicularis	*Roac*	6	1	9	11	1	4	1	1				1
Ribes oxyacanthoides	*Riox*		1	3			1		5				2
Carex spp.[a]	*Carex*	1	42	2	43	16	3	70	34	19	71	1	26
Rubus strigosus	*Rust*	2		3	1	3	7	25	4	47		1	1
Cornus stolonifera	*Cost*	2					1		8		12		
Populus balsamifera	*Poba*						83				81		
Salix spp.[b]	*Salix*			1			20	7	36	24		31	82
Anemone canadensis	*Anca*			2	1	1		2		6	1		1
Taraxacum officinale	*Taof*			1		2		7	1	1			1
Poa spp.	*Poa* spp.				2	1		14	2			4	3
Calamagrostis spp.	*Cal* spp.						1	5		1	8		9
Poa palustris	*Poapa*									63	14	3	2
Carex atherodes	*Caath*			11			7			6	50	74	5

[a] Clusters in horizontal sequence as arranged from right to left along x axis

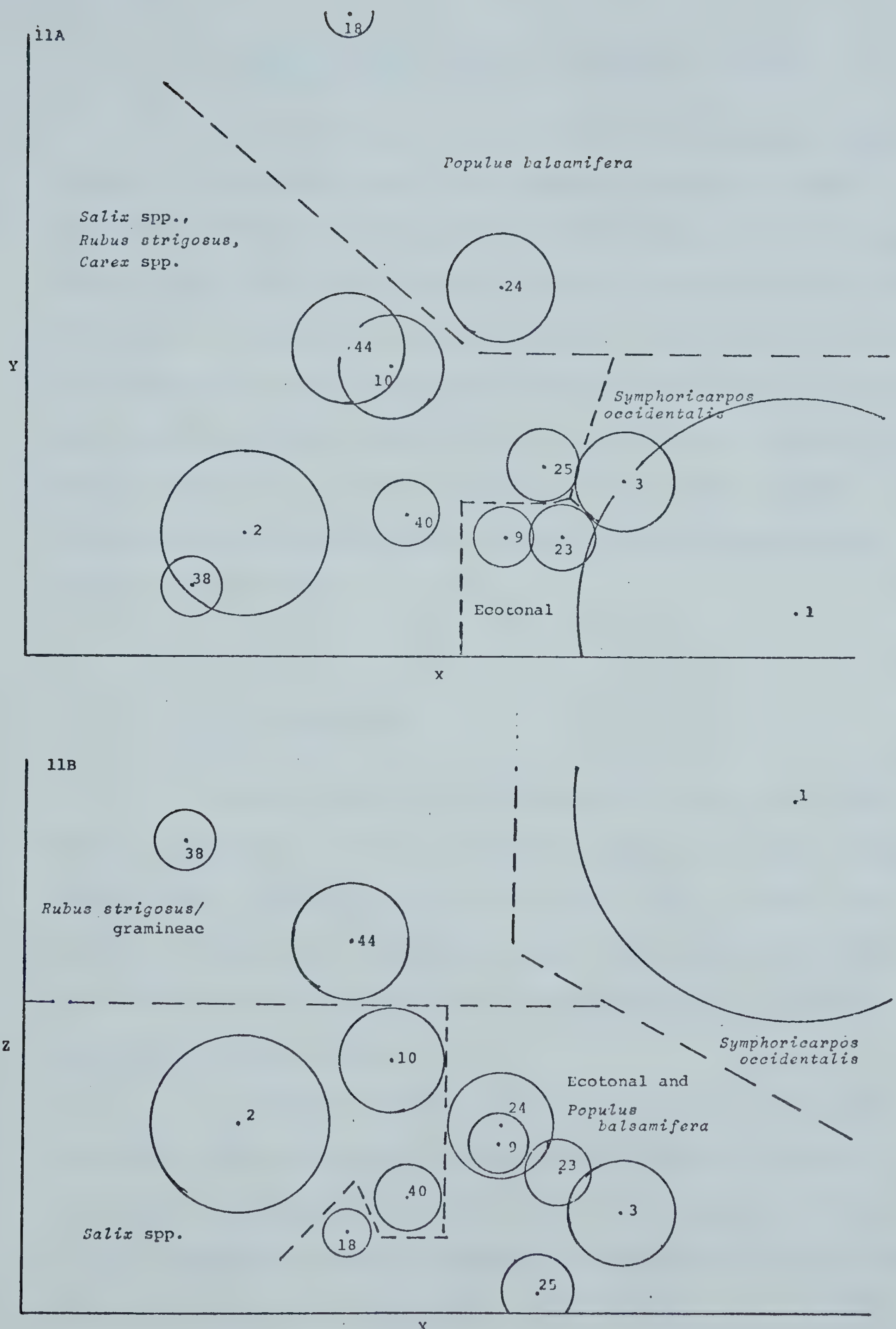
[b] Includes *Salix bebbiana; S. discolor*

Figure 11. Ordination of the non-linked clusters from six groves with *Populus tremuloides* excluded, 1971.

11A. on the XY plane

11B. on the XZ plane

Code	Cluster
1	*Symphoricarpos occidentalis*
2	*Salix* spp.
3	*Symphoricarpos occidentalis/Carex* spp.
9	Ecotonal
10	*Salix* spp./*Carex atherodes*
18	*Populus balsamifera/Carex* spp. (*Carex atherodes*)
23	Ecotonal
24	*Populus balsamifera*
25	*Carex* spp.
38	*Rubus strigosus/Poa palustris*
40	*Salix* spp./*Carex* spp.
44	*Rubus strigosus/Carex* spp.


11A
18
Populus balsamifera
Salix spp.,
Rubus strigosus,
Carex spp.
24
44
10
Symphoricarpos
occidentalis
25
3
2
40
9
23
38
Ecotonal
1
Y
X
11B
1
38
Rubus strigosus/
gramineae
44
Z
10
Symphoricarpos
occidentalis
Ecotonal and
Populus
balsamifera
2
24
9
23
40
3
Salix spp.
18
25
X

9. Basal Area, Height and Age of *Populus tremuloides*

Analyses were run on non-linked clusters, using *Populus tremuloides* basal area, height and age as the variables. There were significant differences in *Populus tremuloides* basal area, height and age among clusters along the X axis. However, closer analysis showed that there were no differences among clusters dominated by *Populus tremuloides.* Only those clusters with little or no *Populus tremuloides,* where *Salix* spp. was the dominant in the tree stratum, differed significantly from those clusters dominated by *Populus tremuloides.*

C. Plot Ordination

Species cover values from 1970 data were used in the ordination of the communities (plots) on the north, south, east, and west aspects of groves two, three, four and ten. Four main community types were recognized from plot distribution patterns and the boundaries of these were drawn (Figure 12).

At one end of the X axis were found *Salix* spp. dominated communities and at the other, medium *Populus tremuloides* communities. Small and large *Populus tremuloides* communities were centrally located along the X axis but were separated along both Y and Z axes.

Within the three main *Populus tremuloides* communities, plots were distributed along the X axis in

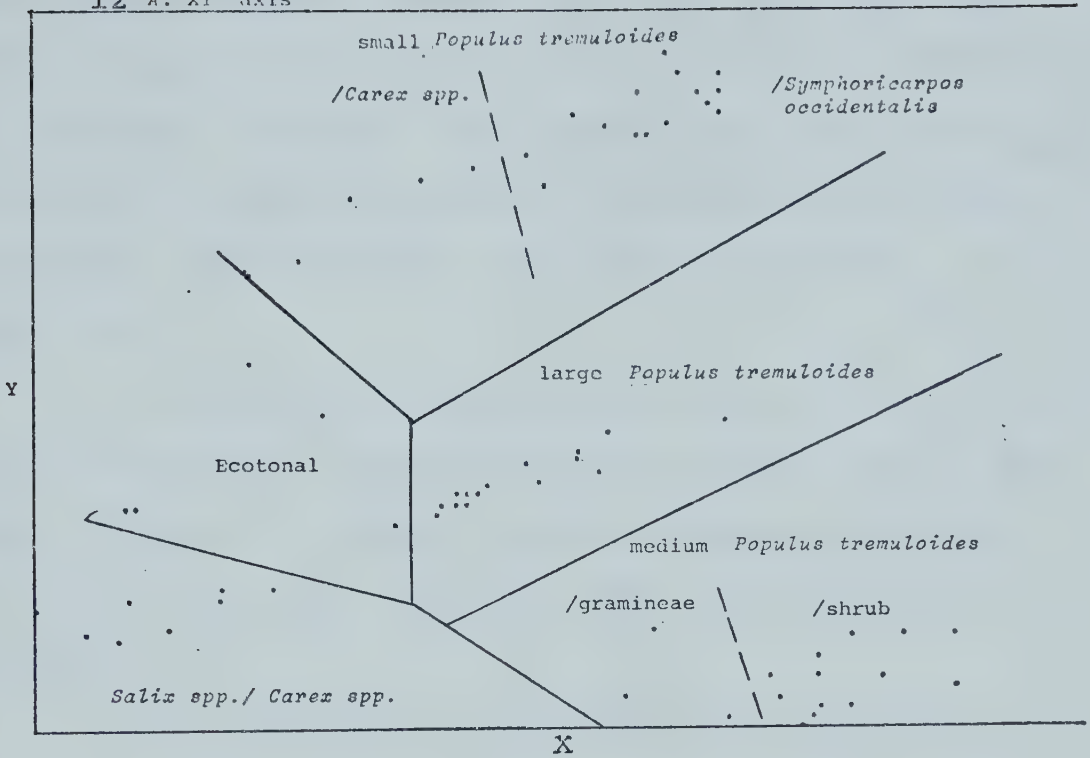
Figure 12. Ordination of the plots from four groves, 1970.

12A. XY axis

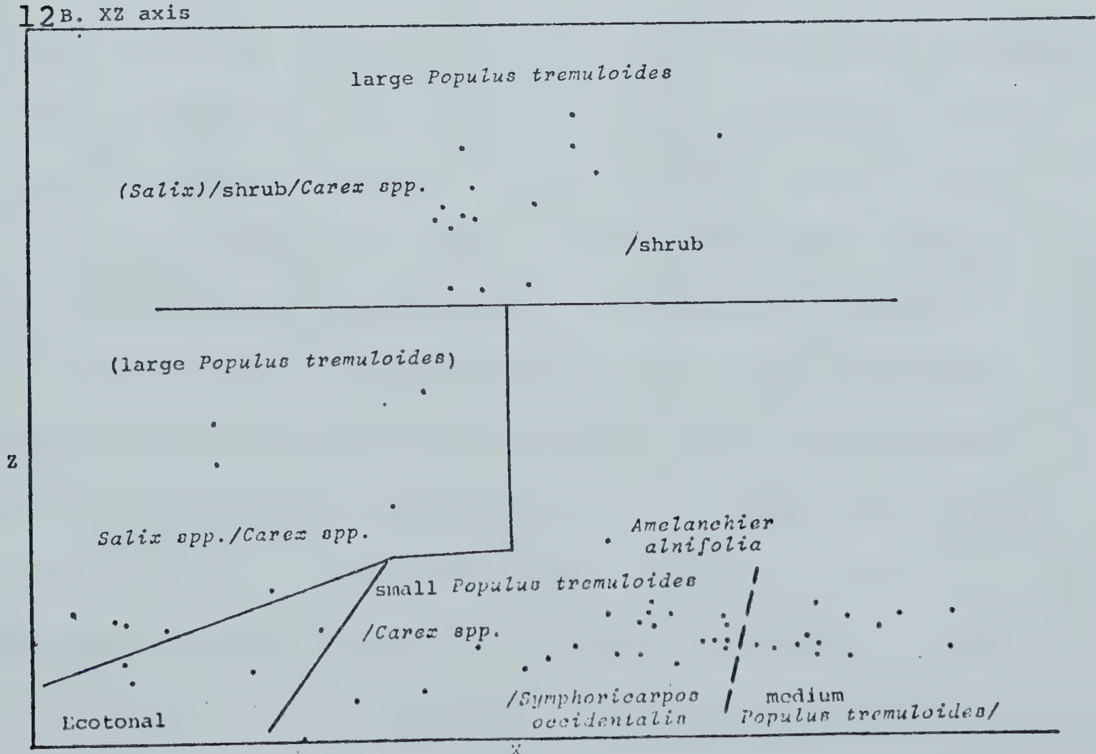
12B. XZ axis

Code	Community Type
Salix/Carex	*Salix* spp./*Carex*
Salix	*Salix* spp.
Carex	*Carex* spp.
Potr	*Populus tremuloides*
Caath	*Carex atherodes*
Rust	*Rubus strigosus*
Syoc	*Symphoricarpos occidentalis*
Amal	*Amelanchier alnifolia*
gramineae	mixed grass species dominating the understory
shrub	mixed dominance of one or more shrub species
s	small trees (*Potr*) 0 - 8.9 cm DBH
m	medium 9.0 - 17.8 cm DBH
l	large > 17.8 cm DBH

12 A. XY axis



12B. XZ axis



a similar pattern. That is, those plots with high cover values for *Carex* spp. and with little *Symphoricarpos occidentalis* were located furthest left and their opposites, furthest right. Plots with intermediate values of both were centrally located. This pattern was more definite in the small and medium *Populus tremuloides* communities than in the large, *Populus tremuloides* community (Figure 12).

A second ordination was performed in which *Populus tremuloides* was not distinguished by diameter class. The results (Figure 13) showed a greater degree of continua although the four main community types could still be identified.

When all plots in six groves were ordinated using 1971 vegetation data, four main vegetation groups were again evident (Figure 14) but some continuity existed. The small and medium *Populus* groups were separated along the X axis while the Y axis lifted the *Salix* spp. group. The Z axis separated the large *Populus* dominated plots. The four main groups each seemed to occupy an apex of a three dimensional triangle. Along the Y axis, ecotonal plots between the *Salix* spp. group and the large *Populus tremuloides* group were numerous and not easily separated from either group. However, along the X axis, the shrub/small *Populus tremuloides* plots which had low tree cover could be distinguished from those plots dominated

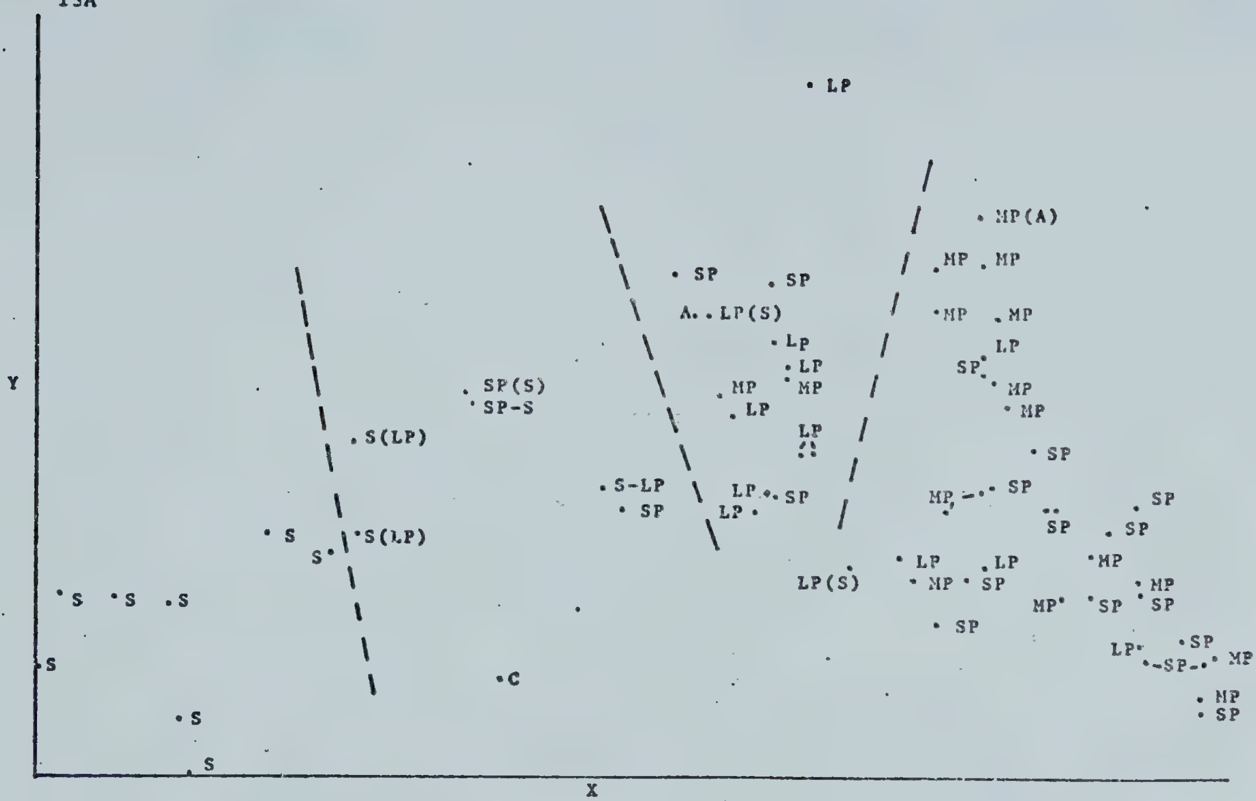
Figure 13. Ordination of plots of four groves, 1970, in which *Populus tremuloides* was not distinguished by diameter class prior to ordination.

13A. XY axis

13B. XZ axis

Code	Definition
A	*Amelanchier alnifolia*
SP	small *Populus tremuloides*
MP	medium *Populus tremuloides*
LP	large *Populus tremuloides*
S	*Salix* spp.
C	*Carex* spp.
( )	subdominance
-	codominance

13A


Y
X
S
S(LP)
SP(S)
SP-S
S-LP
SP
LP
LP(S)
MP
MP(A)
C
A

13B

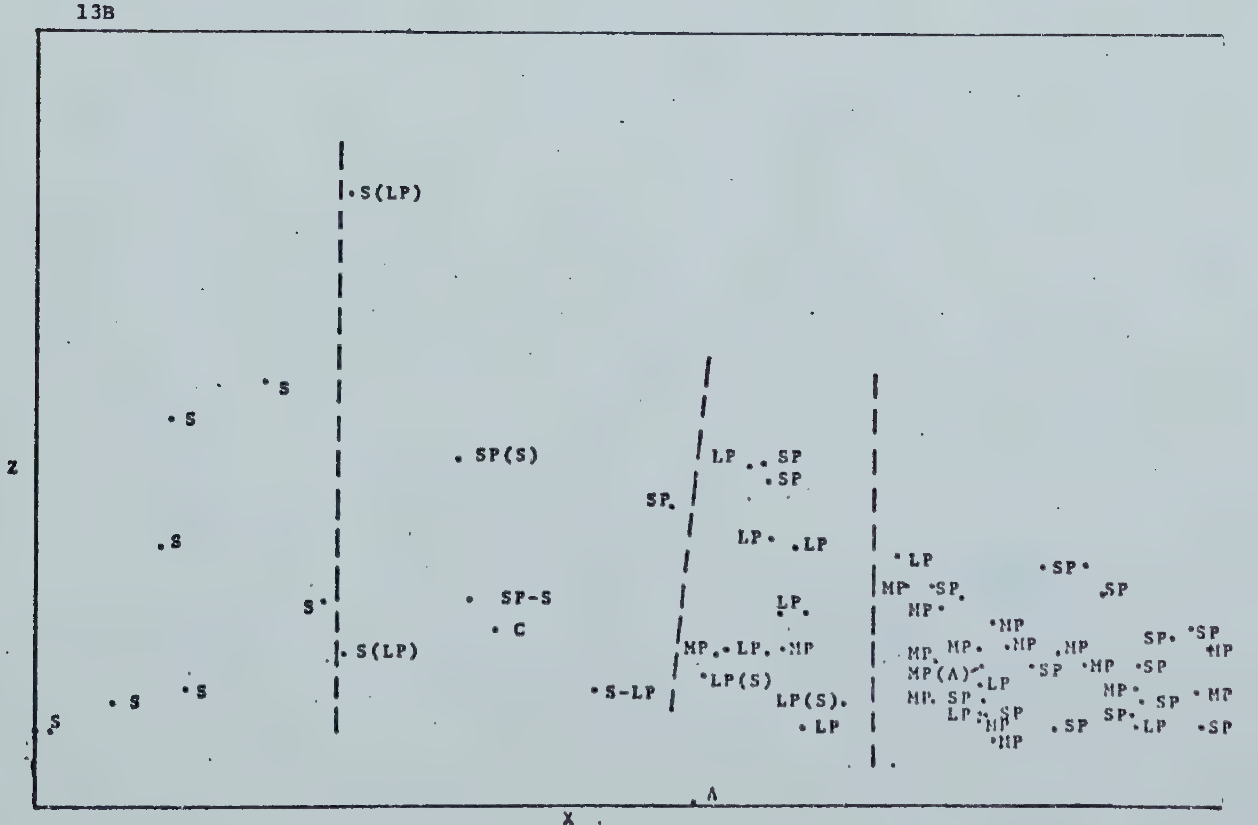
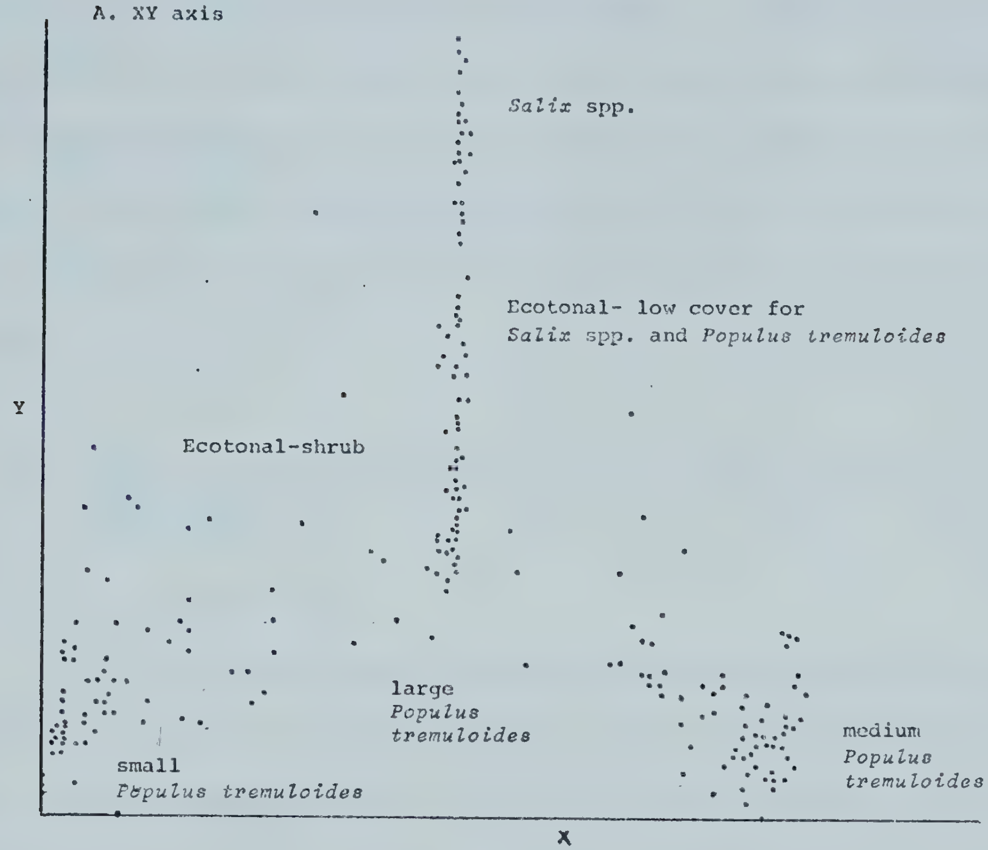
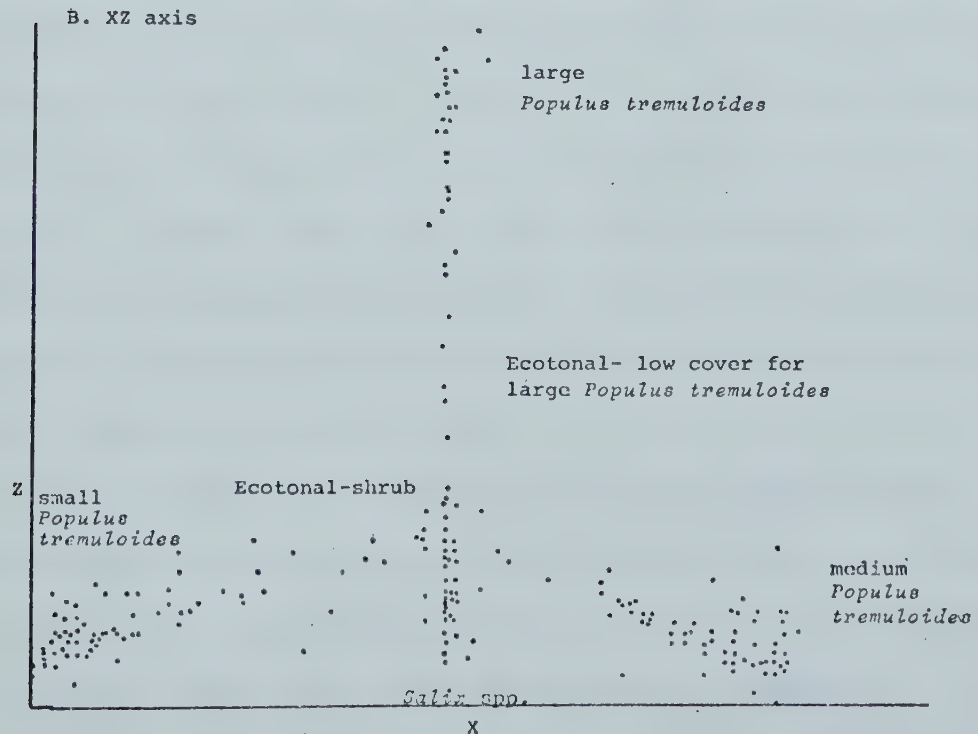

Z
X
S
S(LP)
SP(S)
SP-S
C
S-LP
SP
LP
LP(S)
MP
MP(A)
A

Figure 14. Ordination of plots from six groves, 1971.





by small or medium *Populus tremuloides*. The low cover large *Populus tremuloides* plots were also distinguishable from predominately *Salix* spp. or dominant large *Populus* plots. The most continuous aspect of the vegetation was that between *Salix* spp. and large *Populus tremuloides* plots.

D. Relationship of *Populus tremuloides* Growth to Topography

1. Basal Area

To compare basal area of *Populus tremuloides* among the four aspects it was necessary, due to restrictions of the computer program used, to divide the analysis into two replications. The first representing results from plot one comparisons and the second, results from plot two comparisons of basal area. Since the results were similar, however, only those from plot one will be included in Table 10. Basal area was found to be significantly lower on the south-facing aspect than on the other three aspects. There was a difference of 13.8 m^2/hectare between the highest and lowest basal area.

The two plot replications were compared for the effect of slope position on *Populus* basal area but since they did not differ significantly from an analysis of all plots together, only the one was included.

TABLE 10

Relationship of *Populus tremuloides* Basal Area,[a] Height, Age and Diameter[b] to Aspect, Position on Slope[c] and Grove Number, 1971

Aspect	Basal Area (m^2/ha)	Height (m)	Age (years)	Diameter Closest Trees	Breast Height (cm), Felled Trees
E	19.5 a	5.2 a	14.2 a	7.9	9.6
W	19.5 a	3.7 a	10.3 a	6.4	11.2
N	17.5 a	6.1 a	13.1 a	7.6	9.1
S	6.1 b	2.0 b	5.5 b	5.8	8.4
F value	5.30**	3.44*	4.06**	1.05ns	0.83ns
Position on Slope					
6	17.3 a	6.0 a	15.0 a	4.3 c	5.6 bc
5	24.7 a	7.6 a	19.5 a	6.8 bc	3.1 ab
4	26.0 a	7.9 a	21.7 a	9.6 ab	10.9 ab
3	21.2 a	6.6 a	19.9 a	11.7 a	13.7 a
2	12.8 a	4.3 a	12.9 a	8.4 ab	13.2 ab
1	2.3 b	0.6 b	1.9 b	4.8 c	6.3 c
F value	23.14**	23.36**	21.45**	10.28**	8.67**
Groves					
2	26.7 a	6.7	19.9	8.6	
3	13.4 a	4.0	11.2	8.1	
4	15.3 a	4.2	11.2	7.9	
5	12.9 a	5.9	16.2	6.3	
8	8.7 b	3.3	9.4	8.1	
10	12.4 a	3.8	10.7	6.6	
F value	2.98*	1.66ns	1.93ns	1.11ns	

[a] Means for basal area, height and age were geometrically scaled to $\log_{10}$ in order to reduce the influence of one or two very large or small values in calculation of means.

[b] Means for DBH are arithmetic. F tests based on arithmetic means. Duncan's tests based on geometric means.

[c] Slope positions are from grassland edge (6) downslope to slough edge (1).

Basal area differed significantly among positions. Position one (closest to the slough edge) had lower basal area than remaining positions (Table 10). Slope position four, midway upslope, had the highest basal area of *Populus tremuloides*, with 23 m^2/ hectare more than that of position one. The largest basal area found in the study area was 71.3 m^2/ hectare at position four on the east aspect of grove ten.

All plots were combined to analyze the influence of individual groves on *Populus tremuloides* basal area. All groves were similar with the exception of grove eight, which had a significantly lower basal area (Table 10).

2. Height

A division of the analysis into two replications was also necessary to compare height of *Populus tremuloides* over the four aspects. Results showed no difference among aspects for plot one but for plot two, the south-facing aspect had smaller trees than remaining aspects. Trees at position one were approximately 7 m shorter than the tallest trees at position four and were 4 m shorter than the next smallest trees at position two (Table 10). Tree height was the same in the six groves studied. The tallest tree measured was 16.4 m tall (DBH 32.2 cm, age 43 years) and was located in position one on the east aspect of grove five. Although the average heights were much lower, many trees were between 12 and 15 m tall.

3. Age

Age of *Populus tremuloides* followed the same trend as height. That is, one of the two plots showed no difference among aspects; the second plot had a significant difference between trees on the south aspect and remaining trees (Table 10). The south-facing aspect had trees at least 5 to 8 years younger than remaining aspects. Slope position one (closest to the slough edge) had younger trees than those at other positions. Trees on the lowest position were 20 years younger than the oldest trees of position four. No significant differences in age were found among groves, but the mean age ranged from a low of 9.4 years in grove eight to 19.9 years in grove two.

4. Diameter at Breast Height

For the two trees closest to each plot there was no difference in diameter at breast height (DBH) due to aspect (Table 10, only plot one included). Of those trees that were felled for ring counts, half had the diameter measured and the results of analyses of these also showed no difference among aspects. Differences in diameter of *Populus tremuloides* were found in both plots one and two due to position on the slope. Position three had larger trees than those of positions one, six and five. The latter three did not differ significantly from each other, while trees of position three were the same as those of

positions two and four (Table 10). The results for the felled trees were similar, with position three having the largest trees and position six the smallest. No significant difference among groves were found for diameter of *Populus tremuloides*.

E. Invasion of *Populus tremuloides*

The invasion of *Populus tremuloides* over the past sixty years has been considerable. From field notes of the legal land survey (Saint Cyr, 1903), it was found that *Populus tremuloides* occupied 6.7 percent of the area considered. Using aerial photographs taken in 1963, it was calculated that *Populus tremuloides* now occupied 52.2 percent of the same transect lines (Table 11). The increase in *Populus tremuloides* cover averaged 7.6 m/km/annum or 0.76 percent/annum.

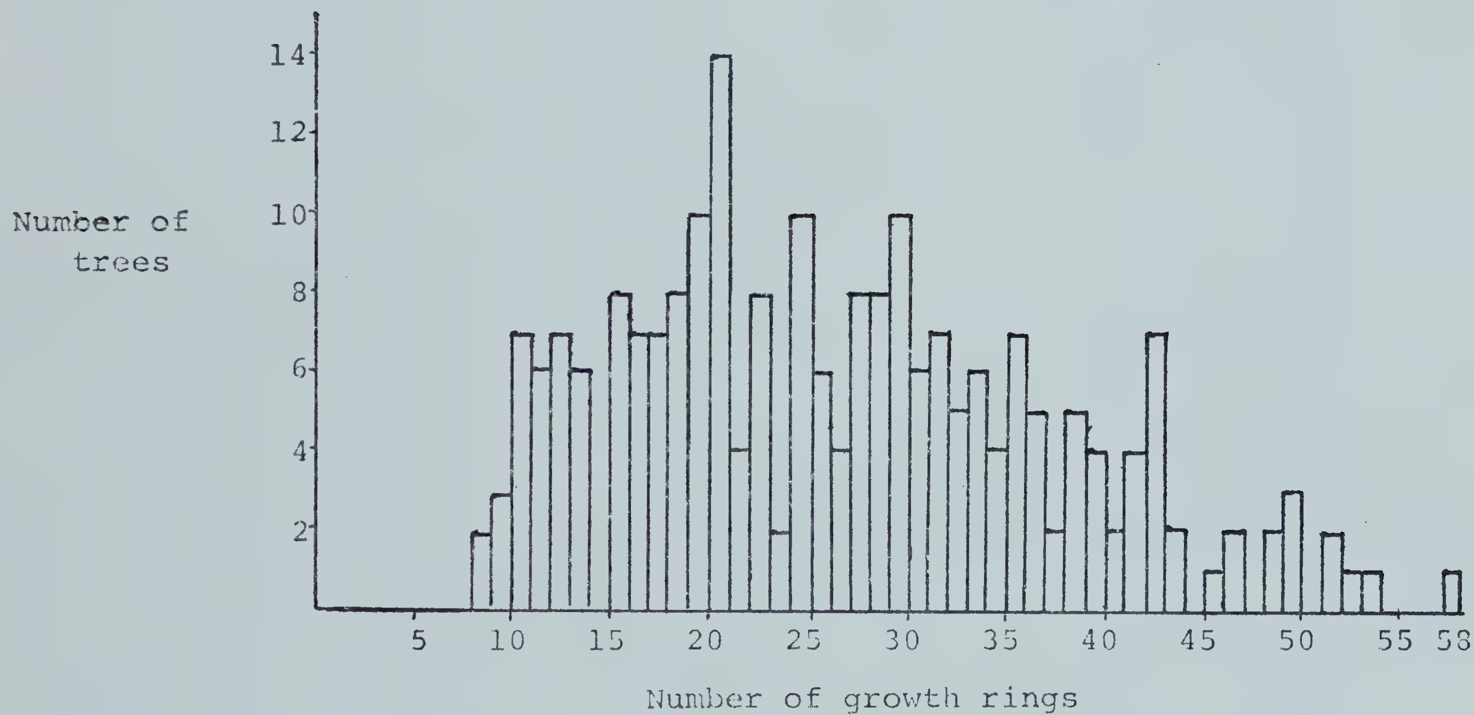
It was felt that if long term climatic records could be correlated with numbers of trees in each age group (Figure 15), then some of the inconsistencies of past invasion of trees might be explained. Since Edmonton city was the closest climatic station for which records had been kept for more than fifty years, data from this station were used. A step wise multiple regression using numbers of trees as the dependent variable and annual precipitation, annual rainfall, previous years rainfall, annual snowfall and previous years snowfall as independent variables accounted for only 1.2 percent of the variability. Since

TABLE 11

Rate of Invasion of *Populus tremuloides* for Twenty-six 1.6 Km. Transects near Kinsella, Alberta.

Transect	Percent of Line Under *Populus*		Increase (%)
	1903	1963	
1	0	0	0
2	8.7	40.0	31.3
3	16.2	60.0	43.8
4	10.1	61.2	51.1
5	0	76.7	76.7
6	0	64.0	64.0
7	23.4	42.0	18.6
8	0	12.0	12.0
9	0	55.8	55.8
10	11.7	35.3	23.6
11	0	23.8	23.8
12	9.9	57.1	47.2
13	0	71.2	71.2
14	0	0	0
15	7.5	20.0	12.5
16	3.7	24.0	20.3
17	3.1	83.7	80.6
18	5.3	50.0	44.7
19	7.9	52.1	44.2
20	18.6	40.7	22.1
21	2.7	63.6	60.9
22	0	23.5	23.5
23	2.8	58.9	56.1
24	14.9	42.2	27.3
25	25.0	78.1	53.1
26	0	43.3	43.3
Total Distance (41.6 km.)	6.7	52.2	45.5

Figure 15. The relationship of number of *Populus tremuloides* trees to estimated age, at Kinsella, 1971.



the sample was fairly small for most age groups, ring counts were accurate only within five years due to rot and false rings, and the area of sampling was not covered by any long term climatic records, further analyses were not conducted.

II. Soils

Soils were classified and sampled for nutrient analysis in a preliminary manner (in 1970). The results were substantiated in greater detail by the 1971 data and hence with the exception of one table, only the 1971 results are included.

A. Classification

In the study area the most abundant soil orders were gleysolic (57%) and chernozemic (39%). Main subgroups represented included:

Humic Eluviated Gleysol	(28%)
Orthic Humic Gleysol	(18%)
Carbonated Humic Gleysol	(6%)
Orthic Dark Grey Chernozem	(19%)
Orthic Black Chernozem	(6%)
Orthic Dark Brown Chernozem	(5%).

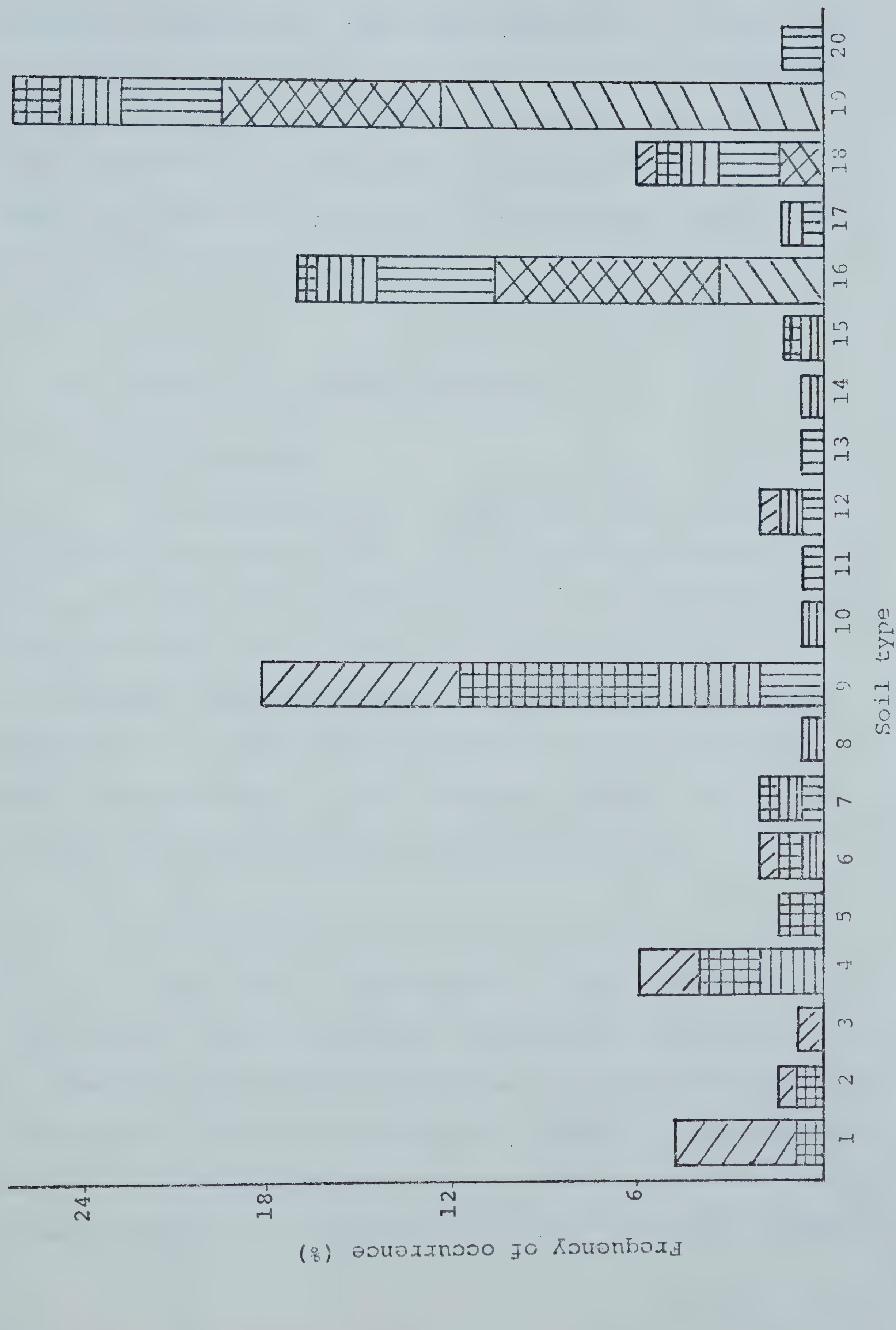
The remaining profiles were classified into fourteen soil subgroups; mainly carbonated, gleyed or rego subgroups of the gleysolic, chernozemic and luvisol orders (Figure 16, Appendix 11).

Although the Humic Eluviated Gleysols were found in all slope positions except the grassland edge (position 6), they were most frequently found in the two positions closest to the slough edge. The lower slope positions were also characteristic of the Orthic Humic Gleysols. The Chernozemic soils, Orthic Black, Orthic Dark Brown and Orthic Dark Grey were located almost exclusively above the mid-slope position, strongly favouring those positions closest to the grassland edge of the groves (positions 5 and 6). A small number of Carbonated Humic Gleysols were found at all slope positions

Figure 16. Frequency distribution (%) of soil subgroups found in six *Populus tremuloides* groves, 1971 (n = 144)

Code	Soil subgroups	Code	Soil subgroups
1	Orthic Dark Brown Chernozem	11	Gleyed Dark Grey Chernozem
2	Carbonated Dark Brown Chernozem	12	Dark Grey Luvisol
3	Gleyed Dark Brown Chernozem	13	Carbonated Dark Grey Luvisol
4	Orthic Black Chernozem	14	Gleyed Dark Grey Luvisol
5	Calcareous Black Chernozem	15	Orthic Gleysol
6	Carbonated Rego Black Chernozem	16	Orthic Humic Gleysol
7	Carbonated Gleyed Rego Black Chernozem	17	Rego Humic Gleysol
8	Gleyed Rego Black Chernozem	18	Carbonated Humic Gleysol
9	Orthic Dark Grey Chernozem	19	Humic Eluviated Gleysol
10	Carbonated Dark Grey Chernozem	20	Carbonated Humic Eluviated Gleysol

Code	Slope position	Code	Slope position
///	1 slough edge	≡	4 upper mid-slope
XXX	2 lower slope	####	5 upper slope
||||	3 lower mid-slope	\\\	6 grassland edge


Frequency of occurrence (%)
24
18
12
6
Soil type
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

except the slough edge. More than one-half of the remaining soil subgroups (14) were found at positions three and four, the mid-slope positions in the aspen groves. None were found in the two positions closest to the slough edge for these positions had predominantly Orthic Humic Gleysols and Humic Eluviated Gleysols.

B. Chemical and Physical Analyses

1. Phosphorus

No differencesin soil phosphorus were found to be attributable to aspect (Table 12). Phosphorus content of the soils did differ with position on slope. The first two positions above the slough edge were higher in phosphorus than the remaining slope positions. No difference in phosphorus content of A or B horizons was found in soils of the four upper slope positions. Soil phosphorus content was highest in grove eight and lowest in groves two and ten.

2. Potassium

There were no differences in soil potassium levels amoung the four aspects. Differences did occur, however, in potassium content of soils of the six slope positions. The soils of the lowest slope positions (nearest the slough edge) had more potassium than soils in the upper positions. Soils in each position in fact seemed to be similar only to those

TABLE 12

Relationship of Soil Phosphorus, Potassium, pH, Sand and Clay to Aspect, Position on Slope and Grove Number, 1971

Aspect[a]	P(ppm)	K(ppm)	pH	Sand(%)	Clay(%)
N (facing)	6.8	503.0	6.4	47.6	25.6
S	5.3	546.8	6.6	44.5	27.2
E	4.7	459.6	6.4	46.8	25.2
W	6.1	568.0	6.4	46.8	25.2
F value	ns[d]	ns	ns	ns	ns
Slope Position[b]					
1	20.5a[c]	756.4a	6.0c	44.4	23.9
2	7.6b	636.8ab	6.3bc	44.3	25.4
3	4.0c	550.9bc	6.8a	46.5	26.7
4	3.0c	476.0cd	6.7ab	47.0	25.6
5	3.3c	402.0d	6.7ab	49.2	24.7
6	3.6c	377.9d	6.5ab	49.3	24.5
F value	21.61**	18.16**	6.37**	2.33*	0.69 ns
Groves					
2	2.8c	474.1bc	6.1cd	42.9c	27.2abc
3	5.6abc	641.5a	6.8ab	43.5c	30.2a
4	5.1bc	367.6d	6.8ab	57.4a	18.5d
5	8.2ab	455.3cd	6.4bc	51.0b	23.6c
8	10.2a	644.2a	5.9d	43.2c	25.2bc
10	3.4c	587.1ab	7.1a	44.0c	28.1ab
F value	7.66**	11.57**	13.75**	19.83**	17.44**

[a] Means for aspect, slope and groves are geometric. Duncan's test for aspects showed no significant differences so the letter 'a' was omitted.

[b] Slope position ranked 1-6 from slough edge upslope to grassland edge of each grove.

[c] Means in vertical sequence followed by the same letter are not significantly different ($P < 0.01$) by Duncan's multiple range test.

[d] $**P < 0.01$; $*P < 0.05$; ns - non-significant.

in the positions directly above them on the slope. The A horizon had fewer differences among positions than did the B horizon and had more potassium in four upper slope positions than did the B horizon. The highest levels of potassium were found in the B horizon of soils in the two positions closest to the slough edge and lowest in B horizons of the two positions closest to the grassland edge. The level of soil potassium was found to be different among groves.

3. pH

No differences in soil pH were found attributable to aspect. The B horizon was slightly higher in pH than the A horizon for all aspects. The pH did differ according to position on slope. Soils of the lowest slope position had the lowest pH. There were differences in pH among groves. Grove eight had more acidic soils than the other groves.

4. Texture

Sand and clay content did not differ among soils on the four aspects (Table 12). The B horizons generally showed less sand and more clay than the A horizons. Although a difference was found for sand content of soils on different slope positions, this difference was not significant when Duncan's multiple range test was used. Again the B horizons showed higher clay content than A horizons.

The highest clay content was found in the B horizon of soils at the slough edge position. The same soils had the least clay in the A horizons. The six groves had differences in soil texture. Grove four soils had the highest sand and least clay content.

C. Soil Moisture and Soil Temperature

1. Statistical Analyses

The analysis of variance tests performed on the data showed that there were no differences among aspects in either soil moisture or soil temperature. Position on the slope as represented by community types was significantly different for both soil moisture and temperature (Table 13). Generally, the *Carex* spp. and *Salix* spp. communities had more soil moisture than *Populus tremuloides* and *Symphoricarpos occidentalis* communities. Differences among slope positions were fewer in July and August than in June. Soil moisture in June was highest at the slough edge (position 1) and lowest at the upper edge of the grove (position 5). The *Salix* spp. edge community (position 2) did have significantly more moisture than did the *Symphoricarpos occidentalis* edge community of position five. In July, the slough edge (position 1) had more moisture than the small *Populus tremuloides* (position 4) with the remainder showing no differences. In August only the slough edge differed from remaining communities.

Soil temperatures in June were highest in position five and lowest in position two. There were no differences among the middle positions two, three and four. In both

TABLE 13

The Relationship of June, July and August Soil Moisture Content and Temperature Values to Position on Slope, 1970

Position on Slope[(a)]	June	Soil Moisture July	August
1	14.2a[(b)]	15.4a	15.3a
2	13.3ab	14.5ab	12.0ab
3	11.4abc	13.2ab	9.6b
4	10.6bc	11.8b	6.3b
5	9.3c	12.7ab	10.6b
F test[(c)]	6.89**	4.03**	5.05**
Position on Slope	**June**	**Soil Temperature July**	**August**
1	10.9ab[(d)]	15.5a	12.7b
2	8.7c	12.5b	12.4b
3	9.3bc	13.2b	12.9b
4	9.0bc	12.0b	12.7b
5	12.2a	13.0b	14.5a
F test	7.62**	9.38**	4.68**

[a] Position 1 *Carex* spp. community at slough edge
2 *Salix* edge community and/or small *Populus*/*Carex*
3 large *Populus tremuloides* community
4 small *Populus tremuloides* community
5 *Symphoricarpos occidentalis* at edge of small *Populus*

[b] Values are % water by weight; means are geometric; those means in vertical sequence followed by a different letter are significantly different ($P < 0.01$), according to Duncan's Multiple Range Test.

[c] F test, $P < 0.01$**, $P < 0.05$*.

[d] Soil temperature values are degrees celsius

July and August, soil temperatures were similar among positions with one exception. In July, position one had significantly higher soil temperature than all the rest and in August, position five had the highest temperature.

2. Ordination of Soil Moisture and Temperature

Communities of groves ten and three found along the moisture and temperature transects were ordinated. The resulting graphs were used as a base to superimpose July soil moisture and temperature data. Those communities grouped through similar species cover values also tended to be congregated as groups having similar moisture values (Figure 17). It was apparent that the X axis was one of moisture, for at one end were those small *Populus tremuloides* communities with low moisture and at the opposite end were the more moist *Salix* spp. communities. Although moisture groupings tended to correlate with communities there was also a related correspondence of moisture to slope position. That is, although all larger circles (Figure 17) did not represent soil moisture within *Salix* spp. communities, they did represent soil moisture for soils located on similarly long or steep slopes, hence their position on the slope was similar to that of the *Salix* spp. communities.

Soil temperatures were found to show less differentiation (Figure 18). The higher temperatures beneath

Figure 17. Ordinational representation of July soil moisture values (%) for selected plots of groves three and ten, 1970.

17A. XY axis

17B. XZ axis

Code	Soil Moisture (%)
∘	8 - 11.5
○	11.6 - 13.5
◯	13.6 - 15.5
⃝	15.6 - 18.2
	Community Type
1	*Salix* spp.
2	Mixed dominance *Salix* - *Populus tremuloides*
3	Large *Populus tremuloides*/gramineae
4	Small, medium *Populus tremuloides*/ *Symphoricarpos occidentalis*

17A

17B

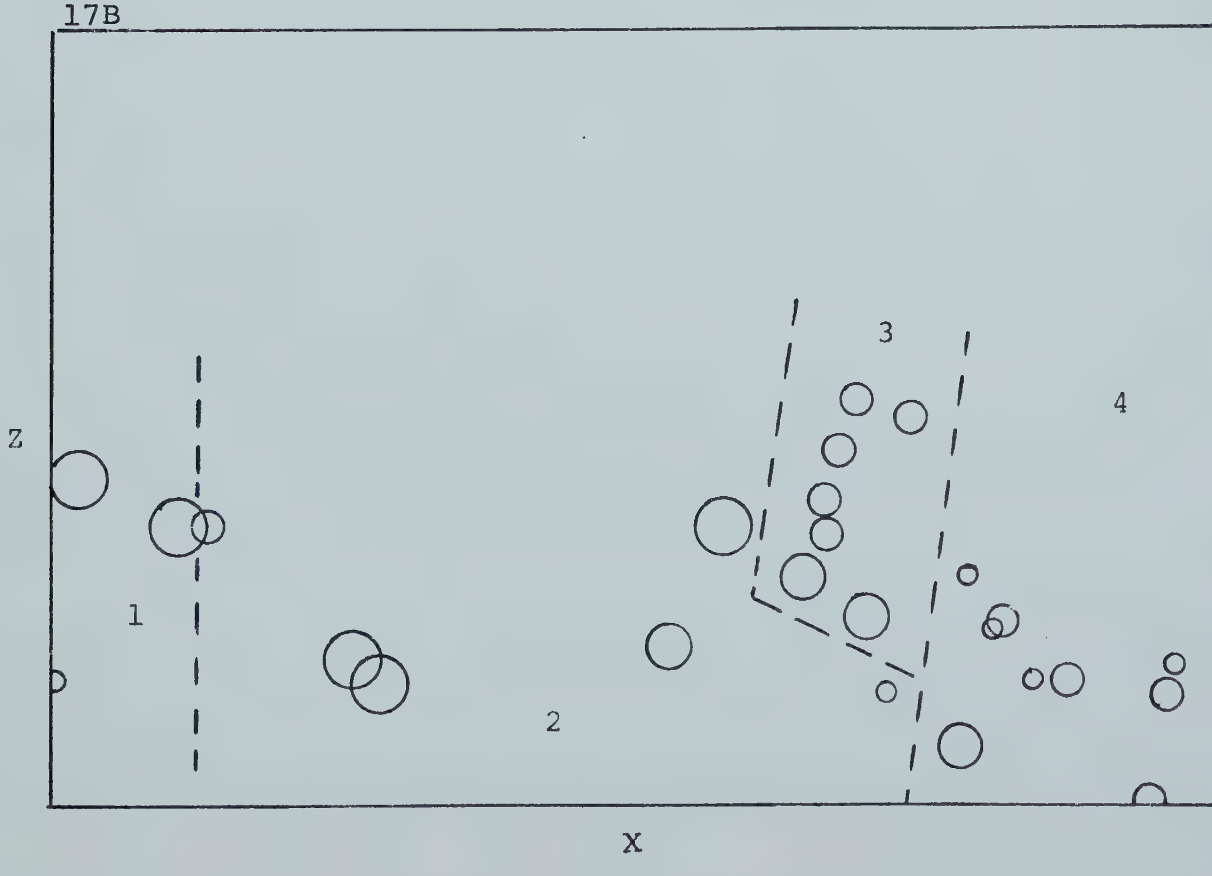


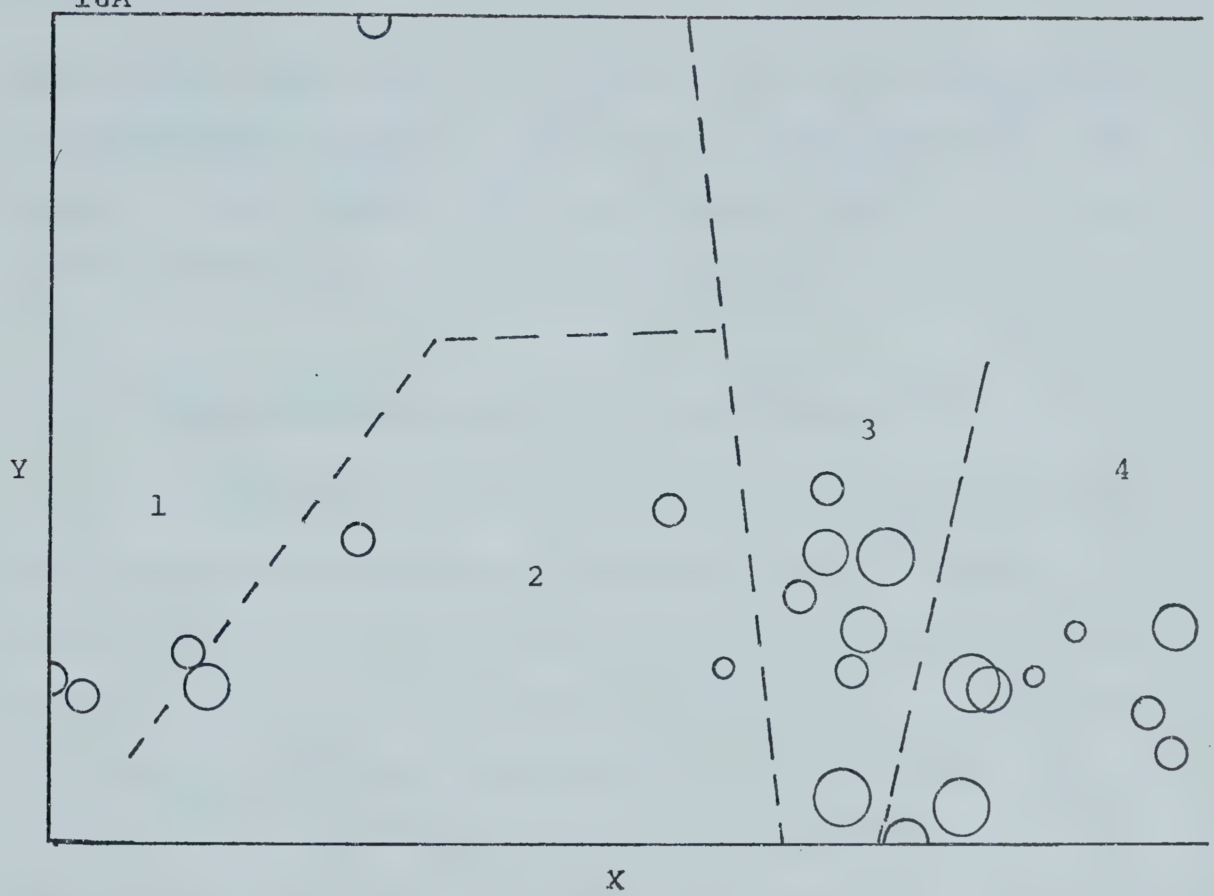
Figure 18. Ordinational representation of July soil temperature values (°C) for selected plots of groves three and ten, 1970.

18A. XY axis

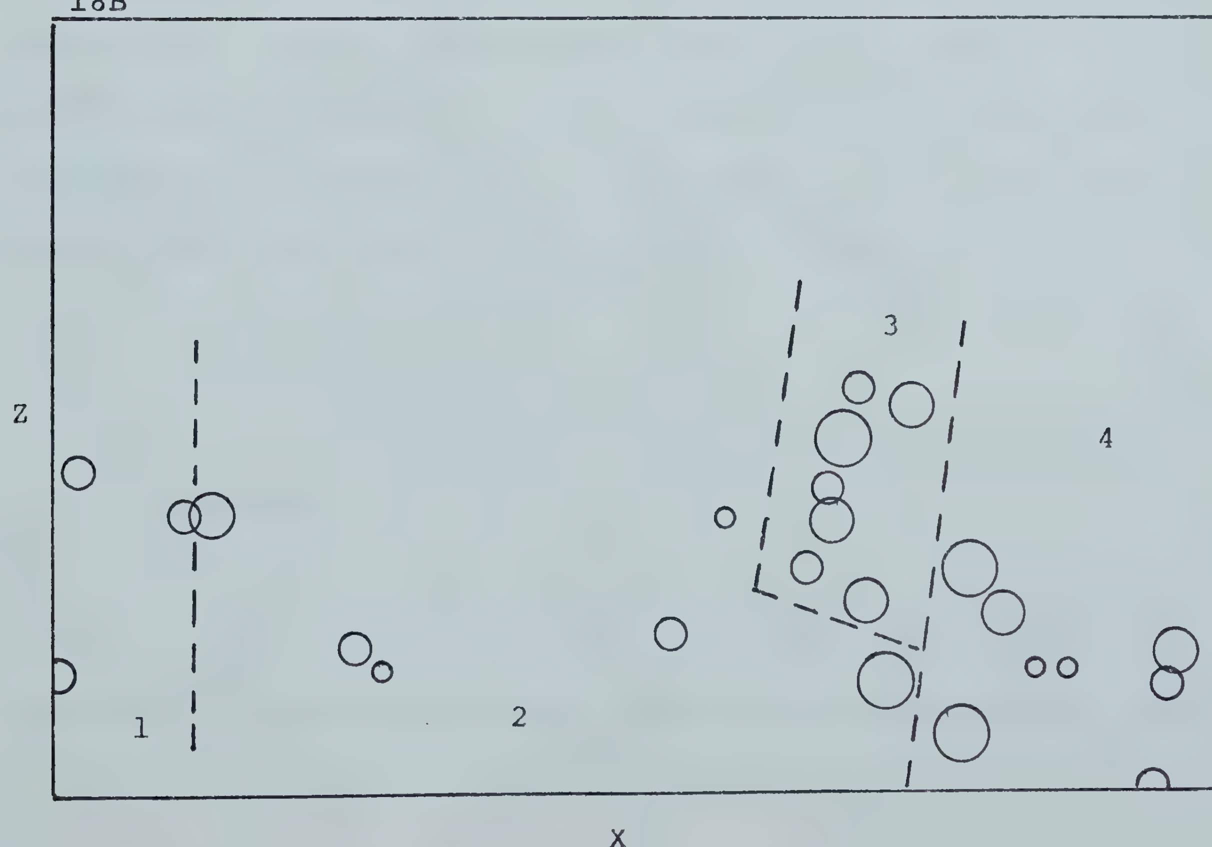
18B. XZ axis

Code	Soil Temperature (°C)
∘	11 - 11.9
○	12 - 12.9
◯	13 - 13.9
◯	14 +
	Community Type
1	*Salix* spp.
2	Mixed dominance *Salix* - *Populus tremuloides*
3	Large *Populus tremuloides*/gramineae
4	Small, medium *Populus tremuloides*/ *Symphoricarpos occidentalis*

18A



18B



old *Populus* were seen as a loose group on XY and XZ axes. It would appear that an axis of soil temperature did not exist. Soil temperatures seemed more closely related to plant community type than to topographical position.

D. Soil Moisture and Snow Relationships

With one or two exceptions, it can be said that the snow accumulation beneath *Populus* was similar or only decreased slightly, from small *Populus* downslope through old *Populus* to the *Salix* community. At the edge of each grove the shrub communities collected much drifted snow from grasslands and hilltops. On the two slopes which had an expanse of brush-free grassland, snow depth was low but it increased downslope as shrubs or *Populus* communities were approached. June moisture also generally increased from grassland to *Populus* but was variable within the *Populus* communities. A significant correlation ($P < .01$) was found between mean snow depth and June soil moisture ($r = +0.42$).

III. Topography

The topographical data collected are presented in Table 14. It can be seen that the maximum slope length found

TABLE 14

Length (m) and Gradient (%) of Slope for Four Aspects and Gradient (%) for Six Positions within the Groves in the Study Area.

a. Length of slope (m) by aspect

Aspect	Grove number						
	2	3	4	5	8	10	Mean
N	29	27	29	35	81	24	37
E	25	30	60	35	52	37	40
S	32	18	32	22	43	20	24
W	29	32	44	35	21	22	30

b. Gradient of slope (%) by aspect

Aspect	Grove number						
	2	3	4	5	8	10	Mean
N	12	11	10	7	13	11	11
E	12	11	17	17	16	10	14
S	2	6	14	14	4	9	8
W	16	7	13	20	11	9	13

c. Gradient of slope (%) at six positions

Position	Grove number						
	2	3	4	5	8	10	Mean
1	3	3	3	1	1	3	3
2	10	7	15	6	4	5	8
3	12	9	18	16	9	11	12
4	10	14	17	21	16	9	14
5	14	11	12	25	16	15	15
6	13	11	17	20	21	14	16

under an aspen grove was 81 m and the steepest slopes in the area were in groves four and five. The south facing slopes were less steep on the average than remaining aspects. The greatest change in percentage slope can be seen between positions one and two and two and three.

IV. Interrelationships Among Vegetation, Soil and Topography

A. Relationship of *Populus tremuloides* to Soil and Topography

A correlation matrix was calculated for *Populus tremuloides*, topographic and edaphic parameters. Many highly significant correlations resulted (Table 15). Basal area was positively correlated with *Populus tremuloides* height, age and diameter and was also positively correlated with slope position and angle and depth of the B horizon. The height and age of *Populus tremuloides* were also positively correlated with slope angle. Basal area, height and age were all negatively correlated with soil phosphorus and potassium.

TABLE 15

Simple Correlation Coefficients for *Populus tremuloides* Parameters and Selected Topographic and Soil Parameters, 1971 (n = 144)

	Basal Area	Height	Age	DBH L[a]	DBH R
Populus height	0.537**[b]				
Populus age	0.523**	0.915**			
Populus DBH L	0.313**	0.482**	0.546**		
Populus DBH R	0.312**	0.493**	0.555**	0.866**	
Slope position	0.206**	0.099	0.016	-0.097	-0.096
Slope angle (%)	0.253**	0.227**	0.157**	0.018	0.031
Sand content	0.024	0.108	0.060	-0.034	-0.047
Clay content	0.048	-0.035	-0.007	0.043	0.073
Phosphorus content	-0.353**	-0.260**	-0.207**	0.031	-0.047
Potassium content	-0.299**	-0.212**	-0.187**	-0.073	-0.060
Soil pH	0.157	0.097	0.074	0.116	0.162**
Depth A horizon	0.071	-0.051	-0.141	-0.267**	-0.180**
Depth B horizon	0.246**	0.088	0.045	0.018	-0.111

[a] DBH L is diameter at breast height of the two trees closest to plot 1; DBH R is diameter at breast height of the two trees closest to plot 2

[b] ** $P < 0.01$

The soil subgroups for each of the sixteen non-linked clusters from four groves (1971) were plotted on the cluster ordination (Figure 19). Those clusters showing linkage to the main sixteen were not included as it was felt that by virtue of the linkage, they would be well enough represented in both soil and vegetation type by the non-linked clusters. Average *Populus tremuloides* age for those plots within each cluster was also included. The results showed the predominance of the gleysolic soils and their association with *Populus tremuloides* of all ages as well as with *Salix* spp. On the left of the X axis the vegetation was basically dominated by *Salix* spp. and little *Populus tremuloides* was found on these Humic Eluviated Gleysols and Humic Gleysols. Medium and large *Populus tremuloides* were more commonly associated with gleysolic soils than was small *Populus tremuloides* under twenty years of age.

B. Relationship of Selected Species to Soil and Topography

Correlation programs were run in 1970 for selected species and soil moisture and temperature (Table 16). In 1971 the program included 23 species, selected edaphic, topographic and *Populus tremuloides* growth parameters. The edaphic and topographic parameters were significantly correlated with species canopy coverage. *Symphoricarpos occidentalis*

Figure 19. Relationship of soil type, *Populus tremuloides* age and dominant vegetation in non-linked clusters, 1971.

Code	Soil Type
HG	Orthic Humic Gleysol
HEG	Humic Eluviated Gleysol
RHG	Rego Humic Gleysol
DGC	Orthic Dark Grey Chernozem
DGL	Orthic Dark Grey Luvisol
0 - 35	Numbers indicate average age of *Populus tremuloides* in the cluster

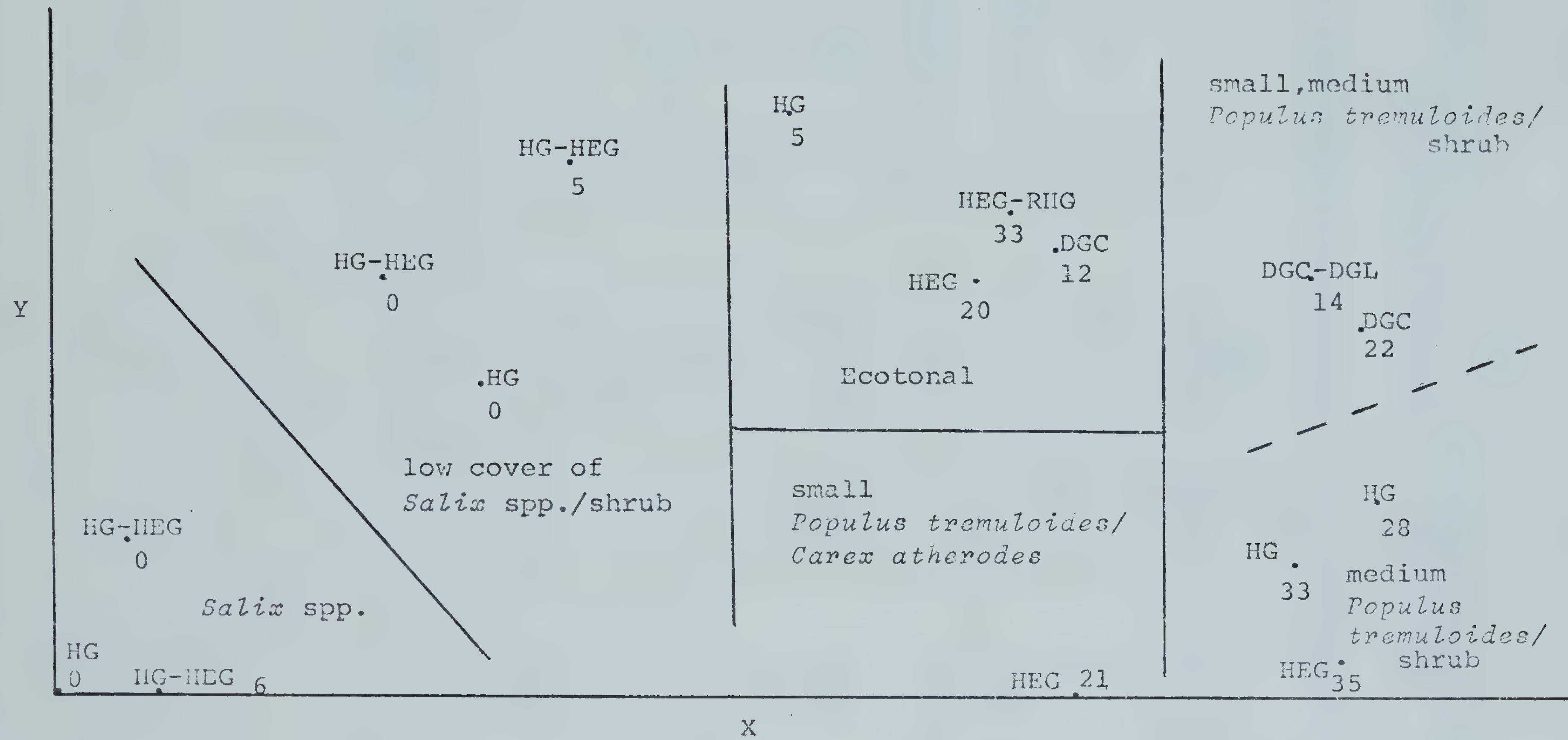

Y
X
HG
0
HG-HEG
6
HG-HEG
0
Salix spp.
HG-HEG
0
HG-HEG
5
.HG
0
low cover of
Salix spp./shrub
HG
5
HEG-RHG
33
.DGC
12
HEG
20
Ecotonal
small
Populus tremuloides/
Carex atherodes
HEG 21
small,medium
Populus tremuloides/
shrub
DGC-DGL
14
DGC
22
HG
28
HG
33
medium
Populus
tremuloides/
shrub
HEG
35

TABLE 16

Simple Correlation Coefficients for Selected Species and Edaphic Characters, 1970 (n = 40).

	July Soil Moisture (%)	July Soil Temperature (°C)
July Soil Moisture (%)	1.00	
July Soil Temperature (°C)	-0.31	1.00
Populus tremuloides[a]	-0.40	0.33
Symphoricarpos occidentalis	-0.61**[b]	0.31
Rosa woodsii	-0.35	0.48*
Viola adunca	-0.55**	0.20
Agropyron spp.	-0.36	0.44*
Salix spp.	0.42*	-0.08
Rubus strigosus	0.38	-0.31
Carex spp.	0.40	0.12

[a]Species values used were canopy coverage % with arc-sin transformation.

[b]**P <0.01; *P <0.05

and *Viola adunca* showed highly significant negative correlations with soil moisture while *Salix* spp. showed a significant positive correlation to soil moisture (Table 16). Only two species showed significant positive correlations with soil temperature. These were *Rosa woodsii* and *Agropyron* spp.

Position on slope and percentage slope had some high correlation values (i.e. $r = 0.40$ to 0.61) followed by potassium ($r = 0.37$ to 0.44) and phosphorus ($r = 0.32$ to 0.38) (Table 17). The pH was correlated with four species, but the correlation values were lower. Sand and clay yielded no highly significant correlations with any species.

Those species showing positive correlations with position on slope included *Populus tremuloides*, *Symphoricarpos occidentalis*, *Rosa woodsii*, *Fragaria virginiana*, *Agropyron* spp., *Viola adunca* and *Galium boreale* while *Salix* spp., *Rubus strigosus*, *Ribes oxyacanthoides*, *Carex* spp., *Poa palustris*, *Calamagrostis* spp. and *Carex atherodes* showed negative correlations with position on slope. Positive correlation with slope percentage occurred for the following species: *Populus tremuloides*, *Symphoricarpos occidentalis*, *Rosa acicularis*, *Amelanchier alnifolia*, *Viola adunca*, *Galium boreale* and *Smilacina stellata*. Those species with negative correlations included: *Salix* spp., *Rubus strigosus*, *Carex* spp., *Poa palustris*, *Calamagrostis*

TABLE 17

Simple Correlation Matrix of Edaphic (n=144), Topographical and *Populus tremuloides* Parameters with Canopy Coverage[a] of 15 Species (n=288), 1971.

	P	K	pH	% Slope	Slope Position	BA	*Populus tremuloides* Height	Age	DBHL	DBHR
Viola adunca	-0.241**	-0.232**	0.242**	0.200**	0.305**	0.223**	0.148*	0.119*	0.014	0.032
Galium boreale	-0.288**	-0.242**	0.085	0.271**	0.457**	0.177**	0.166**	0.144*	0.041	0.051
Thalictrum venulosum	-0.170*	-0.042	-0.098	0.126*	0.103	0.137*	0.127*	0.164**	0.085	0.076
Fragaria virginiana	-0.026	0.025	0.039	0.020	0.204**	0.008	-0.036	-0.032	-0.060	-0.004
Agropyron spp.	-0.131	-0.017	0.225**	0.066	0.281**	0.112	0.069	0.057	0.054	0.058
Festuca scabrella	0.078	0.164	0.033	-0.164**	-0.003	-0.180**	-0.149*	-0.149*	-0.080	-0.097
Amelanchier alnifolia	-0.064	-0.284**	-0.011	0.450**	0.112	0.129*	0.100	0.087	0.127*	0.126*
Symphoricarpos occidentalis	-0.384**	-0.445**	0.194*	0.490**	0.601**	0.305**	0.293**	0.243**	0.021	0.056
Populus tremuloides	-0.319**	-0.427**	0.151	0.306**	0.375**	0.577**	0.532**	0.476**	0.290**	0.272**
Carex spp.	0.249**	0.255**	-0.083	-0.351**	-0.248**	-0.146	-0.192**	-0.118*	0.120	0.103
Salix spp.	0.348**	0.388**	-0.129	-0.407**	-0.529**	-0.539**	-0.506**	-0.442**	-0.212**	-0.213**
Poa palustris	0.347**	0.377**	-0.194*	-0.386**	-0.448**	-0.325**	-0.343**	-0.280**	-0.065	-0.093
Calamagrostis spp.	0.193**	0.250**	-0.233**	-0.313**	-0.388**	-0.179**	-0.119*	-0.104	-0.086	-0.095
Carex atherodes	0.333**	0.310**	-0.164	-0.349**	-0.446**	-0.252**	-0.356**	-0.301**	-0.186**	-0.198**
Taraxacum officinale	0.108	0.228**	-0.063	-0.254**	-0.129	-0.239**	-0.228**	-0.218**	-0.063	-0.047

	Viad	*Gabo*	*Thve*	*Frvi*	*Ag* spp.	*Feso*	*Amal*	*Syoo*	*Potr*	*Carex*	*Salix*	*Poapa*	*Cal* spp.	*Caath*	*Taof*
Viola adunca	1.00														
Galium boreale	0.257**	1.00													
Thalictrum venulosum	0.094	0.250**	1.00												
Fragaria virginiana	0.276**	0.140*	0.099	1.00											
Agropyron spp.	0.153*	0.219**	-0.089	0.243**	1.00										
Festuca scabrella	-0.049	-0.097	-0.134*	0.201**	0.329**	1.00									
Amelanchier alnifolia	-0.017	0.065	0.156**	-0.142*	-0.100	-0.173**	1.00								
Symphoricarpos occidentalis	0.265**	0.461**	0.198**	- .029	0.055	-0.217**	0.096	1.00							
Populus tremuloides	0.207**	0.221**	0.094	0.101	0.106	-0.077	0.104	0.434**	1.00						
Carex spp.	-0.189**	-0.036	-0.078	0.093	0.198**	0.347**	-0.172**	-0.364**	-0.195**	1.00					
Salix spp.	-0.198**	-0.345**	-0.154*	-0.117	-0.235**	0.084	-0.193**	-0.541**	-0.694**	0.230**	1.00				
Poa palustris	-0.227**	-0.282**	-0.165**	0.032	-0.151*	0.191**	-0.158**	-0.526**	-0.379**	0.311**	0.391**	1.00			
Calamagrostis spp.	-0.161**	-0.235**	-0.147*	0.045	-0.145*	0.057	-0.154*	-0.290**	-0.146*	0.137*	0.177**	0.196**	1.00		
Carex atherodes	-0.241**	-0.245**	-0.148*	-0.138*	-0.156**	0.133*	-0.150*	-0.474**	-0.297**	0.205**	0.313**	0.407**	0.301**	1.00	
Taraxacum officinale	-0.064	-0.043	0.028	0.383**	0.133*	0.323**	-0.214**	-0.288**	-0.107	0.314**	0.216**	0.306**	0.135*	0.130*	1.00

[a] * P < 0.05; ** P < 0.01

spp., *Carex atherodes* and *Taraxacum officinale*. For both slope position and percentage slope, the species were divided into two groups, upland species and lowland. The higher canopy coverage of the lowland species were associated with low, gently sloping to level ground, while the upland species showed higher cover values on steeper areas further upslope.

The upland and lowland species groups were correlated with potassium and phosphorus content of the soil. Highly significant positive correlations with potassium and phosphorus were associated with the lowland species including *Salix* spp., *Carex* spp., *Poa palustris*, *Calamagrostis* spp. and *Carex atherodes*. The upland species including *Populus tremuloides*, *Symphoricarpos occidentalis*, *Viola adunca* and *Galium boreale* were negatively correlated with potassium and phosphorus. *Amelanchier alnifolia* was positively correlated with *Agropyron* spp., *Viola adunca* and *Smilacina stellata*, and negatively correlated with *Calamagrostis* spp.

More than one half of the twenty-three species used in the correlation matrix showed highly significant correlations with *Populus tremuloides* parameters including basal area, height, diameter at breast height (DBH) age and canopy coverage. Correlations of the species were consistent over the five parameters. That is, a positive correlation to one parameter was followed by a positive correlation (if any) to the remainder. Only *Populus tremuloides*

positive, and *Carex atherodes* and *Salix* spp., both negative, yielded significant or highly significant correlations to all five parameters. Highly significant correlations to height, age and basal area of *Populus tremuloides* were associated with *Symphoricarpos occidentalis*, *Rosa acicularis*, *Galium boreale*, and *Thalictrum venulosum*, while species yielding negative correlations to those three parameters were *Poa palustris* and *Taraxacum officinale*. *Symphoricarpos occidentalis*, *Galium boreale* and *Poa palustris* were also correlated with *Populus tremuloides* cover. Although *Carex* spp. was negatively correlated with *Populus tremuloides* height, age and canopy coverage, it was not correlated with basal area or DBH. *Viola adunca* was positively correlated only with cover and basal area of *Populus* while *Rosa woodsii* and *Smilacina stellata* showed positive and *Calamagrostis* spp showed negative correlations only with basal area of *Populus tremuloides*. When species to species correlations were calculated it was found that those classified as upland species generally were positively correlated with other upland species and were negatively correlated with lowland species. However, since species distributions could not be considered normal, coefficients could be misleading and are not included here.

C. Relationship of Selected Soil Characters to Vegetation and Topography

The relationships of soil characters with *Populus tremuloides* parameters and with other plant species has been given in the previous paragraphs. However, the correlations of edaphic with topographic parameters were also calculated. Soil texture consisted of sand and clay content. These two soil fractions were highly significantly negatively correlated (Table 18). Sand content was also significantly correlated with slope position and angle, depth of A horizon (all positive) and soil potassium (negative). Clay content yielded significant correlations only with sand content (negative) and soil pH (positive). Soil phosphorus was significantly negatively correlated with all other parameters. The highest correlation was that with potassium ($r = 0.458$). The three highest correlations for potassium ($r = 0.45$-0.50) were negative correlations with slope position and angle and a positive correlation with soil phosphorus. Although potassium was negatively correlated with sand content it was positively correlated with clay content. Soil pH was significantly correlated with all parameters with the exceptions of sand content and depth of B horizon. Its highest correlation was with phosphorus content ($r = -0.325$).

TABLE 18

Simple Correlation Coefficients for Selected Edaphic and Topographic Parameters, 1971

	Slope Position	Slope Angle (%)	Soil, Sand Content	Clay Content	Phosphorus Content	Potassium Content	Soil pH
Slope Position	1.00						
Slope Angle	0.495**[a]	1.00					
Sand Content	0.165**	0.261**	1.00				
Clay Content	-0.064	-0.147**	-0.673**	1.00			
Phosphorus	-0.355	-0.288**	-0.119*	0.131*	1.00		
Potassium	-0.457**	-0.500**	-0.380**	0.242**	0.458**	1.00	
Soil pH	0.212**	0.160**	0.003	0.237**	-0.325**	-0.145*	1.00
Depth A	-0.033	0.031	0.282**	0.104	-0.324**	0.233**	0.315**
Depth B	0.205**	0.028	0.022	-0.097	-0.253**	0.346**	0.058

[a] ** $P < 0.01$; * $p < 0.05$

DISCUSSION

I. Vegetation Analyses.

The results of the cluster/ordination revealed a heterogeneity in the vegetation that was related to the seral nature of aspen vegetation and was also a consequence of methods used. Since the clustering procedure involved a numerical process and the intensity of clustering elicited is a property not only of the basic data, but also of the process to which it is submitted, the existence or non-existence of clusters is not an inalienable property of the data (Williams, 1971). A close examination of the clusters developed from 1971 data revealed that in most groves, only one cluster was formed that grouped at least one-fifth of the plots. The remaining plots did not show enough similarity to be combined into 'replicated' clusters, but were grouped into pairs or left as 'single plot' clusters. Since the species canopy coverage for each 1 m^2 plot was the mean of four 20 x 50 cm quadrats, it is felt that plot size contributed considerably to the degree of variation found among plots. The plot size was probably too small. Canopy coverage values would have been less 'observer biased' if a larger sample size had been used for each mean value. Program dimensions limited the matrix to be analyzed. Instead of dropping two groves in overall analysis (to have a com-

parison with reconaissance), the meter square plots could have been averaged in a number of ways. These included: two 1 m^2 plots/position (to give species canopy coverage as a mean of eight 20 x 50 cm quadrats), two adjacent positions on slope (mean of sixteen quadrats) or even all plots in one position on slope or one aspect, in each grove (mean of 32 or even 48 quadrats). Also, program resolution levels for cluster termination (based on the similarity indices) might have been altered to suit the type of vegetation, without loosing information.

Stand selection for collection of data in 1970 was highly subjective. Stands were defined by the size of *Populus tremuloides* and by dominant understory shrubs. It is interesting however, to compare the results of the four grove cluster analysis of 1970 with that of 1971. Although 1970 'plots' were of the order of eight meters by thirty meters and those of 1971 were one square meter, in both analyses only one major cluster was formed. Almost one-half of the plots used in the 1970 analysis were grouped into one cluster--small, medium *Populus tremuloides/Symphoricarpos occidentalis* cluster. The canopy coverage of *Populus tremuloides* was similar: 92 and 94% (Appendix 12, Table 8). *Symphoricarpos occidentalis* was the dominant shrub with 57 and 42% cover for 1970 and 1971, respectively. The small cover values for other species in the 1971 clusters was probably a result of too small a plot size rather than any

great difference in vegetation. The second largest cluster for 1970 data was comprised of plots dominated by large *Populus tremuloides*. The 1971 analysis showed a *Salix* spp. dominated cluster to be next largest, however, this cluster was only composed of 11/192 plots.

In the above cluster analyses, *Populus tremuloides* was not distinguished by size class. Size class was an inherent feature of plot recognition in 1970 however, but was disregarded in the restricted random location of plots in 1971. When *Populus tremuloides* was distinguished by size class for each plot the results of the 1970 and 1971 ordinations were very similar in spite of the differences in degree of intensity of data collection. Four main vegetation groups were evident on the ordination fields--small, medium and large *Populus tremuloides* and *Salix* spp. dominated. Plots located between the four groups were of an ecotonal nature. Their canopy coverage values were intermediary between those of two types and hence their dissimilarity indices placed them neither in one group of plots nor in the other, but somewhere in between. The majority of these plots provided a continuum between the large *Populus tremuloides* type and *Salix* spp. type. Those species providing the larger amount of variation in canopy coverage included *Populus tremuloides*, *Salix* spp., *Carex prairea*, *Geum allepicum*, *Rubus strigosus*, *Stachys palustris* and *Poa palustris* (Appendices 1 - 4). A greater degree of continuum with less

distinctive 'nodes' was evident on the ordination of 1970 plots when size class was not specifically distinguished in the analysis (size class was inherent in plot selection only).

The separation of the four groups on the ordination fields was felt to be on somewhat of a technical rather than an ecological basis. Since the computer would treat the three size classes of *Populus tremuloides* as individual species having a weight in the distance index dependent on their cover values, it was to be expected that the four community types would be almost equidistantly separated by the three axes. Since species with high cover values influenced the index more strongly when a Euclidean distance measurement was used, plots with high cover of small *Populus tremuloides* would be expected to form a group distinct from those plots with medium *Populus tremuloides*, large *Populus tremuloides* or *Salix* spp. as the dominant species. If these four community types had an ecological basis they should have been more evident in plot ordinations and cluster analyses without *Populus tremuloides* size class distinctions. The *Salix* spp. type was distinct in all analyses but the *Populus tremuloides* dominated plots showed many intergrades when understory species were included.

According to Daubenmire (1966) most studies supporting the continuum viewpoint have (a) included severely disturbed or seral stands almost exclusively and

(b) have ignored population structure and dynamics, and concentrated on species distribution and relative abundance. By these means he felt, they could easily demonstrate a floristic continuum. Assuming some ecological basis for the four main groups identified on the ordination fields (other species besides *Populus tremuloides* did contribute to the similarity indices), the study at hand provided some support for this argument. When population structure was not considered, the many seral stages formed a continuum. The association of the moisture gradient (environmental continuum) with the successional stages (vegetation continuum) provided supporting evidence for the value of the continuum approach to the analysis of the *Populus tremuloides* vegetation. The recognition of diameter size classes in just one dominant species--*Populus tremuloides* resulted in four 'nodes' in the vegetation.

Distortion of vegetation relationships by ecotonal or intermediary gradient position plots (Swan *et al.*, 1969) was present in this study. The 1970 plot ordination and the cluster/ordinations from 1971 data showed the X axis to be a moisture gradient and one of *Populus tremuloides* age succession. However, when *Populus tremuloides* was distinguished by size class, the resulting plot ordinations showed the *Salix* spp. type midway between small and medium *Populus tremuloides* along the X axis. Although the three dimensional position of the *Salix* spp. was at the apex of a

triangle equidistant from each of the *Populus tremuloides* groups, on the X axis its position was unexpected. It is felt that plots representing the ecotonal small *Populus tremuloides* community (small *Populus tremuloides/Symphoricarpos occidentalis (Rosa woodsii))* (Appendix 1) would have been included in the small *Populus tremuloides* group by the computer since the dominant species was *Populus tremuloides*. The understory species of these small *Populus tremuloides* plots included many species common to *Salix* spp. dominated plots and these would influence plot positioning closer to *Salix* spp. and large *Populus tremuloides* groups than to medium *Populus tremuloides* groups. These plots in the field were found in a topographical position between large *Populus tremuloides* and *Salix* spp. dominated communities. They represented *Populus tremuloides* reproduction in positions closer to the slough's edge than where original trees were established--probably a response to lowered water levels in the sloughs over the past ten to fifteen years providing a better habitat for *Populus tremuloides* and less favourable moisture conditions for *Salix* spp.

Within the aspen groves at Kinsella, the vegetation was very heterogeneous and unstable with various age classes of *Populus tremuloides* present. Cluster analysis for individual groves and for four groves together resulted in one main cluster type being recognized although it composed less than one quarter of the plots considered.

This cluster was dominated by small and medium sized *Populus tremuloides* in the overstory, and *Symphoricarpos occidentalis* in the understory. Many plots were combined with one or two other plots into small clusters and many were left as single plot clusters. However, of those clusters dominated by *Populus tremuloides* there were no significant differences with respect to basal area, height or age of *Populus tremuloides*. Age of most *Populus tremuloides* trees in the groves was between ten and forty years (Figure 15). Thirty years was not very long for community development and differentiation. The heterogeneity of vegetation dominated by *Populus tremuloides* would be a result of the seral nature as well as a consequence of plot size used in these analyses. Many species would be trying to become established, some succeeding, others declining. The variations in canopy coverage among the more common species reflect this competition among understory species.

The *Populus tremuloides* dominated plots could be separated from those dominated by *Salix* spp. primarily on the basis of the difference in tree species and secondly on the basis of understory species. Unfortunately *Salix* spp. was not aged in this study, however field observations indicated a decline in dominance of *Salix* spp.. Old trees were most common, many trees were decadent, and young *Populus tremuloides* was present upslope, downslope and among the *Salix* spp. communities. The successional nature of the

vegetation bordering *Salix* spp. communities meant great variation in species presence and average values. Plots representing the ecotonal areas would show greater species variation than plots beneath small and medium *Populus tremuloides* because of (1) less competition for light due to lower canopy coverage of both tree species, (2) better moisture conditions closer to slough's edge, (3) less competition for soil nutrients by the few older trees than by many rapidly growing *Populus tremuloides* trees, (4) many microhabitats provided by differences in soil characteristics in this topographical position (Appendix 11). In both plot ordinations and cluster/ordinations many ecotonal plots provided continuum on the ordination fields between plots or clusters dominated by *Salix* spp. and those dominated by small and medium *Populus tremuloides*. Large *Populus tremuloides* although seemingly distinguishable itself in the field, was not differentiated as a separate community type either by plot ordination or cluster analysis when size itself was not a determining factor in analysis. This type in which older *Populus tremuloides* was the dominant tree appeared only as ecotonal plots between *Salix* spp. and younger *Populus tremuloides* communities.

Analysis of individual groves showed small differences in clusters formed and the dominant species. These variations were probably due to variations in habitat

as related to:

(a) soil characteristics (eg. grove 8 had greater K, P, lower pH.)

(b) topography

(c) land use, especially past grazing intensities

(d) chance establishment of plant species (eg. *Populus balsamifera* in grove 5)

(e) community age (eg. average age of *Populus tremuloides* was significantly less in grove 8).

The *Populus tremuloides* trees in grove eight were younger than those in other groves. In this grove analyses showed *Salix* spp. dominated plots to form a recognizable cluster apart from the main *Populus tremuloides* cluster. Average age of *Populus tremuloides* was oldest in groves two and five. In these groves there was no recognizable *Salix* spp. cluster and there were fewer plots comprising the main *Populus tremuloides* cluster. The groves with age of *Populus tremuloides* midway between the youngest and the oldest, had a small *Salix* spp. cluster and had nearly half of the total plots grouped into a small, medium *Populus tremuloides* cluster. This trend would seem to be consistent with seral vegetation. The *Populus tremuloides* community showed a more recent occupation of landscape surrounding the sloughs or potholes. The *Salix* spp. community seemed to be giving way to an expanding community dominated by *Populus tremuloides*. In grove eight, *Salix* spp. was still evident as a community type but as *Populus tremuloides*

became older it expanded into the *Salix* spp. community. This resulted in a heterogeneous mixture of dominant species in the ecotonal regions and fewer plots designated to any one community type. Where *Populus tremuloides* had been established longest, *Salix* spp. no longer dominated a recognizable group and there were even fewer plots grouped as one *Populus tremuloides* cluster. The *Populus tremuloides* community itself would become more differentiated within, however, plot size used and perhaps plot location resulted in expression of greater heterogeneity among plots rather than separation of vegetation entities.

The ordination of species cover values (Figure 3) also gave an indication of the habitat preferences of the species. *Symphoricarpos occidentalis* appeared to become the dominant shrub where *Populus tremuloides* trees were small to medium in diameter and had high canopy coverage values. It was thereby associated with early successional stages of the *Populus tremuloides* community and gave way to other species as the *Populus tremuloides* became better established. Although *Rosa woodsii* had fewer very high (85 - 98%) cover values than *Symphoricarpos occidentalis* the general distribution of both species (greater cover associated with small and medium *Populus tremuloides*, declining along X axis towards *Salix* spp. communities) showed their similarity in successional position and habitat preferences. *Rosa woodsii* seemed to give way to

Rosa acicularis with increasing age of the *Populus tremuloides* community since plots of high cover of *Symphoricarpos occidentalis* and *Rosa woodsii* contained little or no *Rosa acicularis.* However, field differentiation of the two *Rosa* species was difficult. The lower average cover values of *Rosa acicularis* and *Ribes oxyacanthoides* found most commonly in association with large and hence older *Populus tremuloides* indicated less struggle for dominance among shrubs. The shrubs had either found a more stable level of existence or they were loosing ground to forbs (Table 7).

The plant species found at Kinsella corresponded well with common species in the aspen consociation of Moss (1955) both in the parkland and further north. Hilton (1970) working in the parkland at Kinsella distinguished four communities: small poplar, large poplar, poplar-willow and wet meadows or marshes. He did not separate small and medium poplar, however, his community types were subjectively delimited and used more for productivity studies. In the Peace River area the closed forest contained many similar species to those in the parkland but also included species such as: *Delphinium glaucum* and *Elymus innovatus* (Jeffery, 1961). The aspen-willow forest had *Populus tremuloides* as an understory to *Salix bebbiana* and associated species were *Rosa acicularis, Fragaria glauca, Thalictrum venulosum, Symphoricarpos*

occidentalis, (similar to Kinsella) and *Elymus innovatus*, *Arctostaphylus uva ursi* and *Pulsatilla ludoviciana*. Bird (1930) found the main species associated with *Populus tremuloides* in the aspen edge community in Manitoba were *Symphoricarpos albus*, *Corylus americana*, *Prunus virginiana*, *Rosa blanda* and *Viola canadensis*. His mature aspen forest contained such species as *Corylus americana*, *Cornus stolonifera*, *Viburnum opulus americanum*, *Rosa blanda*, *Rhamus alnifolia*, *Symphoricarpos albus*, some of which were not found in the parkland at Kinsella.

The associations recognized in Montana (Lynch, 1955), Minnesota and Wisconsin (Kittredge, 1938), and Michigan (Gates, 1930) were based on codominant and subdominant species not found in the central Alberta parkland; some of the species were *Osmorrhiza occidentalis*, *Acer saccharum*, *Betula papyrifera*, *Populus grandidentata*, *Pteris aquilinas* and *Diervilla diervilla*.

II. Populus Growth Analyses

From the results found one can safely conclude that the south-facing aspect and the position closest to the slough edge were least favourable for the growth of *Populus tremuloides*. Differences in tree basal area and height were attributable to aspect. Stoeckeler (1960) found aspect to influence *Populus tremuloides* growth through its influence on water relations. A lower Site Index for *Populus tremuloides* on south and southwest aspects has been attributed to greater evapotranspiration on these aspects (Fralish, 1972). The oldest and tallest trees were located at a midslope position (position 4) which also had the largest basal area. There were, however, no statistically significant differences among the positions with the exception of the lowest position. The positive correlations of *Populus tremuloides* parameters with slope position and angle also confirmed this trend. Although basal area, height, age and diameters were least in positions one, young *Populus tremuloides* trees were found in the *Salix* community at the slough edge. This would indicate that *Populus tremuloides* was indeed finding favourable habitat in increasing proximity to the slough edges. Whether or not the trees originated from seed or suckers was not investigated. However, due to the rather rigid requirements for seed germination (Moss, 1938) one

could expect suckers that originate in shallow, lateral parent roots (Gifford, 1966; Maini, 1968; Sandberg and Schneider, 1953) and receive nutrients and moisture from these roots, would have a better competitive advantage. Seedlings, however, are more shade tolerant than suckers (Wiegle and Frothingham, 1911). The young trees at the upper edge of the groves seemed to present the opposite extremity in ecological conditions but sapling trees were found extending into both *Symphoricarpos occidentalis* and grassland communities. These saplings could utilize soil moisture from the slough through connection of roots of individual trees within clones yet have the advantage of good aeration. Many factors are felt to influence or stimulate suckering, including light (Sandberg and Schneider, 1953), removal of apical dominance (Steneker, 1972), increased soil temperatures (Maini, 1960; Maini and Horton, 1966; Shirley, 1931) as well as age, vigor, root thickness and depth, soil aeration, vegetative competition and ecological disturbances (Maini, 1968). Which of the factors are retarding or stimulating sucker growth at either edge of the aspen groves is very difficult to conclude.

What also must be mentioned is that the sloughs are tending to dry up (many had water only in the centre in 1970, 1971 and had *Salix* spp. growing out into the *Carex* spp. community where aerial photos of 1963 indicated standing water to the slough edges), and are thus themselves

providing a more favourable habitat to the *Populus tremuloides* that was previously held back by excessive moisture levels. In Saskatchewan, Maini (1960) found *Salix* spp. to be drying up its habitat through transpiration.

The extension of *Populus tremuloides* into grassland on a large scale over the past sixty years was not found in this study to be correlated with precipitation records. Recent studies (Bailey and Wroe, 1974) have shown invasions of *Populus tremuloides* into *Festuca scabrella* grassland to be related to high growing season temperatures, particularly during the month of June one and two years prior to establishment. Low May to September and annual precipitation two years prior to establishment were negatively correlated with rate of tree establishment.

Although difficulty arose in distinguishing *Salix* spp. from *Populus tremuloides* on the aerial photographs, a ring of *Salix* spp. was accounted for in measurements and it was felt that the majority of the forest measured was dominated by *Populus tremuloides* in 1963. The early survey had a considerable area of *Salix* spp. delimited,however, by 1963 *Populus tremuloides* was felt to be codominant in most of these areas. Hence, where the two were indistinguishable, it was felt safe to accord the area to *Populus tremuloides*. Observations in the field supported this conclusion.

The invasion rate in the Kinsella region, estimated as 7.6 m per km or 0.76 percent per year was considerably

higher than the increase found by Bailey and Wroe (1974) in central Alberta of 0.4 to 0.8 m per year and that of Maini (1960) in Saskatchewan of 0.3 to 0.8 m per year. However, Johnston and Smoliak (1968) estimated a rate of invasion of 0.75 percent per year in south-western Alberta. The climate of the latter area(Porcupine Hills) would be more similar to that at Kinsella than would the climate of Wroe's study area on the southern edge of the aspen parkland. The Porcupine Hills and the northern parklands receive more effective precipitation than the southern edge of the parklands.

Previous studies have shown that factors retarding or slowing the advance of *Populus tremuloides* included fire (Buell and Cantlon, 1959; Hansen, 1949 and Maini, 1960), soil drainage and moisture (Ewing, 1928; Jeffery, 1961) exposure (Carpenter, 1935), soil nutrients (Aikman and Smelser,1938; Fuller, 1923; Maini, 1960) and cattle browsing and trampling (Johnston *et al.*, 1970). All of these factors have a possible influence on spread of *Populus tremuloides* outward from individual sloughs at Kinsella or on this portion of the parkland as a whole when compared to other areas of aspen parkland.

III. Soils

Soils under *Populus tremuloides* were commonly poorly drained. In association with the increased soil moisture near sloughs was increased eluviation. Six main soil types were identified with the Humic Eluviated Gleysols being most common. The soil subgroups located at the lower 'break' of many slopes was apparently influenced by the action of ground water and root respiration that together resulted in recarbonation of B and even A horizons. There were frequently varying degrees of mottling associated with soils at the break in the slope. Soils of upper slope positions were variable due mainly to degree of slope and position on slope as related to surrounding topographic and drainage patterns. Depth to till and vegetative cover also influenced soil type. Leskiw (1971) noted that elevation of topography above the water table had less influence on local recharge and discharge than might be expected. He felt the complex patterns of water movement suggested that local heterogeneities in texture and permeability of the parent material affected soil development. That the soils on upper slope positions were more commonly Dark Grey Chernozems than Black or Dark Brown Chernozems is evidence that the process of degradation and eluviation was occurring even where *Populus tremuloides* trees were less than twenty years old. The Chernozemic soils were generally associated

with small and medium *Populus tremuloides* while gleysolic soils were found under large and medium *Populus tremuloides* as well as under *Salix* spp. communities. The eluviation of the Chernozemic soils was felt to be of recent origin (Pettapiece, 1969). Recent invasion by *Populus tremuloides* was also suggested by the cover comparisons of 1963 aerial photographs with the 1903 land survey.

In this study, no differences in soil phosphorus, potassium, pH, sand or clay were attributable to aspect. Position on slope influenced soil phosphorus levels however. A negative correlation of soil phosphorus with slope position was observed. The lower slope positions had significantly higher phosphorus. Lower phosphorus in upper slope positions was felt to be attributable in part to the presence of free lime. Many carbonated soil types were identified where there was a positive change in slope angle and above. The presence of the free calcium carbonate would increase the proportion of phosphorus present in the relatively insoluble form of Ca-P (Alexander and Robertson, 1968; Teakle, 1928). Since Ca-P was not found to be correlated with available phosphorus (Alexander and Robertson, 1968) and the solubility of Ca-P was depressed due to presence of Ca ion and to Ca+ in the presence of OH- (Teakle, 1928), available phosphorus in these soils would be less than in the more acidic

soils. Available phosphorus in the more developed soils of the lowest slope position would probably be in the Fe-P and Al-P forms (Alexander and Robertson, 1968) or as phosphates released from the iron and aluminum fixation substances by hydroxy-organic acids (Dalton, Russell and Sieling, 1952; Struthers and Sieling, 1948). The movement and distribution of organic phosphorus can also play a significant role in the availability of phosphorus in the soil. The role of *Populus tremuloides* in phosphorus availability is also a factor to be studied as indicated by the significant negative correlation between soil phosphorus and *Populus tremuloides* parameters.

Potassium levels were also found to be correlated with position on slope. Highest levels of potassium were found in lowest slope positions, especially in B horizons. Since potassium is released during the decomposition of organic matter, is easily leached and can be adsorbed to exchange sites on clay minerals, the mobile potassium ions would tend to move downward in the profile and accumulate in the horizons with greater clay content.

It was not determined whether the potassium levels at lowest slope positions were high due to greater leaching at these moist sites or to larger amounts of potassium being released from decomposition of vegetation in the *Salix* spp. dominated community as compared to those

dominated by *Populus tremuloides* and/or *Symphoricarpos occidentalis* . Availability of potassium seemed to be dependent upon degree of leaching, clay and organic matter content, vegetation type and slope position.

The trend in pH was related to slope position, degree of leaching and calcium levels. Where moisture accumulated as at the slough edges, leaching was greatest and basic cations were moved downward leaving acidic upper horizons. While pH values of the small *Populus tremuloides* soils were probably a result of parent material and some downslope cation leaching, the low pH of *Salix* spp. A horizons were probably a consequence of eluviation within the profile itself. The pH levels of soils of large *Populus tremuloides* communities were probably closely related to the free lime content. Higher calcium levels at the break in slope were a result of recarbonation caused by fluctuating water table levels.[3] The variable nature of nutrient levels and soil textures among the groves showed the highly variable nature of the soil parent material in the study area. The nutrient levels could also be influenced by drainage patterns of the area, directly affected by the irregular topography of the hummocky morraine.

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[3] Peters, T.W. September, 1970. Personal communication.

The most moist soils were in close proximity to the slough. This was indicated by an analysis of variance as well as by ordinational representation. Only in June was the moisture of the *Salix* edge community significantly greater than that of any higher position. That is, within the aspen groves moisture did not differ significantly in July and August. The lowest soil moisture for grasslands occurred in June while those for *Populus* communities occurred in August. The grasslands have earlier snowmelt, warmer soils and earlier growth than the treed communities, depleting water reserves earlier. However, soils under forest cover can benefit in spring from heat conducted down tree trunks which melts the snow around the base and thaws the soil. Moisture then penetrates the soil instead of running off over frozen ground (Vil'yams, 1968). Forest soil is permeable even when frozen because it has many non-capillary pores remaining open after the water in capillary pores has frozen (Lutz and Chandler, 1946). In August the differential water use between forest and grassland (Brown and Thompson, 1965) became apparent. In 1970 soil moisture in the grassland was greater in August than in June while the moisture values for *Populus* communities were considerably lower in August than in June. The grassy hilltops generally had the lowest soil moisture values but on the East and West aspects of groves ten and three, soil moisture

in August in the *Populus tremuloides* communities was less than that of the adjacent grassland communities. It would seem that the woody vegetation transpired much more water than did the grassland under the stress of high daytime temperatures of late summer. Since the greater reserves of moisture were found in the sloughs, one effect of the greater transpiration of woody vegetation would be to draw moisture from the sloughs, causing these to slowly dry up. This seemed to be in effect in the study area where both young *Salix* spp. and *Populus tremuloides* were found growing far out into the slough itself, in spite of a series of wet years in the parkland from 1966-1972 (Environment Canada, 1966-1972).

Some authors (Lutz and Chandler, 1946 and Shul'gin, 1965) have observed that exposure and degree of slope influence soil temperature. In this study, soil temperature was not influenced substantially by aspect for the periods of measurement. No major differences in temperatures were found among positions directly beneath *Populus tremuloides*. There was a lack of relationship between soil moisture values averaged over all horizons and temperature values at a 15 cm depth. In fact the correlation coefficient for moisture with temperature was $r = -0.28$ and was not significant ($P < 0.05$). Only very generally could one say that soil moisture increased from grassland to slough edge while

temperature decreased. Soil temperatures on all slopes in July and August were fairly close in value but those for June were consistently lower than in the later months. Soil moisture values in July were generally highest while those of August were lowest. More than two years data are necessary to make any definite predictions for moisture-temperature relations at Kinsella.

The great variability in snow depth within aspen groves was probably due to the variability in topography surrounding and within a grove. The effect of surrounding hills, shrub patches and aspen groves on drainage and on wind would influence soil moisture and snow depths. Soil moisture was influenced to some degree by snow depth, as the correlation between June moisture and average snow depth was highly significant. Further study on winter snow conditions may help to explain soil moisture regimes during the growing season.

Soil nutrient levels appeared to be related not only to soil reaction and topography but to growth of *Populus tremuloides*. Grove eight which had the highest levels of phosphorus and potassium and most acidic soils also had the youngest *Populus tremuloides* trees and lowest basal area. Grove two with lowest phosphorus levels had the oldest *Populus tremuloides* trees. A significant negative correlation occurred between *Populus tremuloides* basal area, height and age with soil phosphorus and potassium. Dormaar

and Lutwick (1966) observed that total and organic phosphorus decreased in the soils sequence from Black Chernozems to Dark Grey Luvisols in Southwestern Alberta. With the advance of trees, both soil nitrogen and organic phosphorus were found to decrease (Lutwick and Dormaar, 1968). Since *Populus tremuloides* leaf fall is high in silica, iron, aluminum, calcium, potassium (Volobuev, 1964), nitrogen and phosphorus (Daubenmire, 1953), the largest additions to the soil would be expected to come from the small *Populus tremuloides* trees in upper slope positions due to dense growth habit. However, the high levels of phosphorus and potassium were found instead under the *Salix* spp. community. Does *Populus tremuloides* decrease levels of soil nutrients; does the *Salix* spp. community add an even greater amount of nutrients through leaf fall; or are physical or environmental factors playing the dominant role in determining nutrient levels?

Wilde and Zeher (1948) in Wisconsin, observed aspen growth to be best on sandy soil but no positive correlation of *Populus tremuloides* basal area, height or age with sand was found in the present study. Correlations of *Populus tremuloides* growth (as measured by site index) with soil texture were found by other researchers (Meyer, 1956; Stoeckeler, 1960; Voigt *et al.*, 1957) but were not indicated in this study. Stoeckeler (1960) felt, however, that in areas having lower rainfall than Minnesota, i.e.

central Alberta, slope, aspect and exposure would be of greater importance than silt and clay content of soils. Although no correlation of *Populus tremuloides* growth with pH was observed, grove eight with the most acidic soil did have the least basal area of *Populus tremuloides*. Stoeckeler (1961) found for the Lake States the *Populus tremuloides* site index was greater on lime soils than on acidic soils. Clonal differences in *Populus tremuloides* growth may also have contributed to differences in *Populus tremuloides* growth among groves (Zahner and Crawford, 1965). In this study, growth of *Populus tremuloides* seemed most favoured in upper slope positions away from slough edge, where slopes were steeper and soils were lower in phosphorus and potassium but had good depth of B horizon.

Degradation of chernozemic soils by advance of *Populus tremuloides* was observed by several authors (Pettapiece, 1969; St Arnaud and Whiteside, 1964; Dormaar and Lutwick, 1966). This included decreased depth of the Ah horizon, increased litter layer, decreased pH, development of an impoverished, platey Ae, development of a more textural B and a decrease in nitrogen, phosphorus and lime accumulation.

The processes of podzolization or eluviation that are associated with forest vegetation cause the movement of organic materials and sesquioxides from upper horizons into B horizon. The mechanism of organic metal complexes that precipitate out in lower horizons due to oxidation,

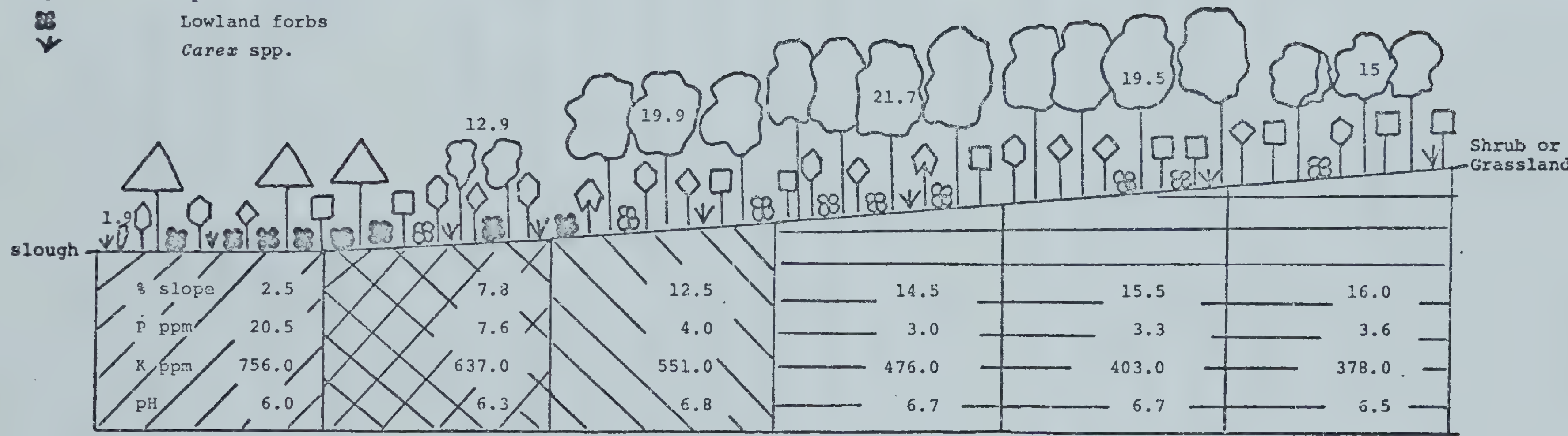
destruction of the ligands or loss of ligand effectiveness with time, has been used to explain the migration of Fe, Al and Mn ions (Bloomfield, 1954; Crawford, 1965; Kaurichev and Nozdrunova, 1969; Schuylenborgh, 1965; and Stobbe and Wright, 1959). St Arnaud and Whiteside (1964) found no significant increase in nitrogen or organic carbon in the layer of greatest iron accumulation and felt that the role of organic matter could not be definitely understood.

The gradual change in soil subgroups with the increasing age of *Populus tremuloides* indicated the beginning of eluviation of soils under the *Populus tremuloides* community. However, the development and chemistry of the soils in mid-slope positions (correlating to oldest *Populus tremuloides* trees) seemed to be also directly related to topographical influences.

The correlation analyses reinforced the results of vegetation and soil analyses. However, the lack of normality in distribution of species canopy coverage, and many of the soil and topographical parameters would cause some obscurity in relationships (Goodall, 1973). The correlations of species cover with soil and topographical parameters can only be broadly assessed as falling into two groups, an upland and a lowland group. A negative or positive correlation to one or two of the characteristics did not automatically ensure the same correlation to remaining characteristics of the group. A summary of the relationships found within the aspen groves can be seen by the following profile diagram (Figure 20).

Figure 20 Profile diagram of an average slope showing relationships of vegetative, edaphic and topographic characters within an aspen grove.

Code	Definition
	Salix spp.
	Rubus strigosus
	Ribes oxyacanthoides
	Rosa spp.
	Symphoricarpos occidentalis
	Populus tremuloides
	Upland forbs
	Lowland forbs
	Carex spp.



Scale Slope Length 1 mm = 0.17 m

Populus tremuloides Parameters (as per Table 10)

Basal area m/h - 0 - 6
7 - 15
15 - 22
23+

Height - length from base line to top of tree at scale 1 mm = 0.3 m
Age - typed figure in or above *Populus* trees.

Soil Parameters - Code

Code	Subgroup
///	Humic Eluviated Gleysol
\\\	Orthic Humic Gleysol
≡	Orthic Dark Grey Chernozem

SUMMARY

The study was conducted at Kinsella in the aspen parkland of east central Alberta from January 1970 to November, 1971. The objectives were to investigate interrelationships of vegetation, soil and topographical factors within the aspen groves. Invasion of *Populus tremuloides* into grassland was also examined.

1. The reconnaissance study was undertaken in the summer of 1970. Canopy coverage data were collected in four groves using plot frames and overall visual estimates of species cover in stands. Representative soil pits were dug in two groves and soils were classified and sampled for nutrient analysis. Soil moisture and temperature samples were taken in June, July and August.

2. Cluster analysis of the vegetative data showed clusters differentiated predominantly on the basis of seven species: *Populus tremuloides*, *Salix* spp., *Symphoricarpos occidentalis*, *Rubus strigosus*, *Carex* spp., *Poa* spp., and *Rosa* spp.

Many single plot clusters were left in each grove analysis. One cluster type was found repeated in all six groves. This was small, medium *Populus tremuloides/Symphoricarpos occidentalis*. When clusters were ordinated, the X axis was interpreted as (a) a moisture gradient, (b) a gradient of increasing position upslope from the slough edge and (c) a successional gradient.

3. Plot ordination separated the four main community types of small, medium and large *Populus tremuloides* and *Salix* spp. communities. Distances between the communities indicated their relative dissimilarities. The ordination program was based on an index of dissimilarity which was influenced by the number of species comparisons between two plots and the actual cover values of species. The many species occurring frequently throughout the aspen groves reduced dissimilarity indices. However, the separation of *Populus tremuloides* with its high cover values into three size classes meant that for many plot comparisons, it was possible to have two species of high cover, each occurring in only one of the two plots and thus both species contributing their actual cover values to the index. The result of indentifying

Populus tremuloides by size classes was the separation of plots almost solely on the basis of two factors--*Populus tremuloides* diameter size class and presence or absence of *Salix* spp. When *Populus* size was not differentiated, the large *Populus tremuloides* plots did not form a definitive group, but remained as intergrades between the *Salix* spp. and smaller *Populus tremuloides*.

4. The more commonly occurring species found in the aspen groves included the forbs: *Galium boreale*, *Taraxacum officinale*, *Viola adunca*, *Fragaria virginiana* var. *glauca*, *Vicia americana*, *Lathyrus ochroleucus* and *Anemone canadensis*. The common shrubs were: *Rubus strigosus*, *Symphoricarpos occidentalis*, *Rosa woodsii* and *Rosa acicularis*; the sedges were: *Carex atherodes*, *Carex prairea* and other less common *Carex* species. The understory species showed habitat preferences in terms of association with *Salix* spp. or with *Populus tremuloides*. A few species common to the wetter habitat under *Salix* spp. were not found in small or medium *Populus tremuloides* community types; however, nearly all of the species of the latter habitats were also found closer to the slough edge. The most species rich communities occurred between the edge of the slough and the break in

slope. This region was felt to represent a zone of fluctuating water levels that presently favoured succession towards *Populus tremuloides* dominance.

5. The south aspect was least favourable to *Populus tremuloides* growth, represented by basal area, height and age. Only the position nearest the slough edge was statistically different from other positions with respect to growth of *Populus tremuloides*. The most favourable position was position four, generally located just above or at the change in slope curvature and degree, where soils were lower in phosphorus and potassium than down slope positions.

6. Invasion of aspen into grassland has been substantial over the past sixty years. A comparison of 1903 land surveys and aerial photographs of 1963 showed an increase of 7.6 m per km per year in the Kinsella region of the parkland. Judging from a number of factors: (a) slightly higher soil temperature in the *Symphoricarpos occidentalis* communities (favouring suckering), (b) insignificant moisture differences between aspen forest and *Symphoricarpos occidentalis* community and (c) number of young saplings (suckers) growing at a distance from the groves' edge, one can assume that this invasion by *Populus tremuloides* will continue in the future.

7. Six main soil types were identified, with the most frequent being the Humic Eluviated Gleysols.

8. Phosphorus levels were lowest under large *Populus* communities and highest in soils beneath *Salix* spp. communities. These levels were felt to be related to free lime in the soils under *Populus*, and to clay and organic matter content in the soils under *Salix* spp. Soil potassium content increased downslope in a regular fashion. The greatest difference in pH was noted for the soils beneath large *Populus*, in which the apparent presence of redeposited lime resulted in increased pH levels. No differences in soil phosphorus, potassium, pH or texture were attributable to aspect, but significant differences were attributable to slope position.

9. Soil moisture was found to increase from grassland to slough edge but there was less than a five percent difference in moisture content among soils within the aspen groves. Soil temperature showed less than one degree difference among positions within the aspen groves in June, July and August, 1970, 1971. No relationship was found between soil moisture and temperature, probably due to differences in sampling depth.

10. The species were divided into upland and lowland groups in the correlation matrix. The upland group consisted of species having positive correlations with slope position and degree of slope (angle), and negative correlation with soil phosphorus and potassium. These upland species also showed numerous positive correlations with *Populus tremuloides* parameters. The lowland group of species yielded negative correlations with *Populus tremuloides* parameters and indicated association with low, gently sloping to level topographical position in which soils were higher in phosphorus and potassium.

Significant correlations were found to exist among soil nutrient and *Populus tremuloides* growth parameters, however, the interaction of topographical factors prevented definition of any cause-effect relationship. Further studies may elucidate more exactly the influence of *Populus tremuloides* and associated vegetation on soils in the east central Alberta parkland.

LITERATURE CITED

AIKMAN, J.M. and SMELSER, A.W. 1938. The structure and environment of forest communities in central Iowa. Ecol. 19:141-150.

ALEXANDER, T.G. and ROBERTSON, J.A. 1968. Inorganic Phosphorus forms in some Alberta soils as related to soil development, parent material and available phosphorus. Can J. Soil Sci. 48:289-295.

ANONYMOUS. 1974. The system of soil classification for Canada. Can. Dept. of Agr. Pub:1455. 255pp.

BAILEY, A.W. and WROE, R.A. 1974. Aspen invasion in a portion of the Alberta parklands. Jour. Range Man. 27(4):263-266.

BEALS, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bull. 72:156-181.

BIRD, R.D. 1930. Biotic communities of the aspen parkland of central Canada. Ecol. 11:256-442.

BIRD, R.D. 1961. Ecology of the aspen parkland of western Canada. Can. Dept. of Agr. Pub:1066, Ottawa 153pp.

BLOOMFIELD, C. 1954. A study of Podzolization. V: The mobilization of iron and aluminum by aspen and ash leaves. J. Soil Sci. 5:50-56.

BOUYOUCOS, G.J. 1951. A recalibration of the hydrometer method for making mechanical analyses of soils. J. Amer. Soc. Agron. 43:434-438.

BRAY, J.R. and CURTIS, J.T. 1957. An ordination of the upland forest community of southern Wisconsin. Ecol. Mono. 27:325-349.

BROWN, H.E. and THOMPSON, J.R. 1965. Summer water use by aspen, spruce and grassland in western Colorado. J. For. 63:756-760.

BUELL, M.F. and CANTLON, J.E. 1959. A study of two forest stands in Minesota with an interpretation of the prairie forest margin. Ecol. 32:294-316.

CARMICHAEL, J.W. 1970. The taxmap classification program. Dept. Bacteriology. Univ. of Alberta. (Published by Carmichael and Sneath (1969)).

CARMICHAEL, J.W., GEORGE, J.A. and JULIUS, R.S. 1968. Finding natural clusters. Syst. Zool. 17(2): 144-150.

CARPENTER, J.R. 1935. Fluctuations of biotic communities in prairie forest ecotone of Central Illinois. Ecol. 16:203-212.

CRAWFORD, D.V. 1965. Some processes of podzolization. In Hallsworth, F.G. and Crawford, D.V. Experimental Pedology, London, Butterworths, p. 267-281.

DALTON, J.D., RUSSEL, G.C. and SEILING, D.H. 1952. Effect of organic matter on phosphate availability. Soil Sci. 73:173-181.

DAUBENMIRE, R. 1953. Nutrient content of leaf litter of trees in northern Rocky Mountains. Ecol. 34: 786-793.

DAUBENMIRE, R. 1959. A canopy coverage method of vegetational analysis. North West Sci. 33:43-64.

DAUBENMIRE, R. 1966. Vegetation: Identification of typal communities. Sci. 151:291-298.

DAY, M.W. 1944. The root system of aspen. Amer. Midland Nat. 32(2):502-509.

DORMAAR, J.F. and LUTWICK, L.E. 1966. A biosequence of soils of the rough fescue prairie--poplar transition in southwestern Alberta. Can. Jour. Earth Sci. 3:457-471.

EHRENREICH, J.H. 1962. Measurement and evaluation of soil moisture and temperature and microclimate in ecological studies. In J.P. Blaisdell, chairman Range Research Methods Symposium, Denver, Col., May 1962. U.S.D.A. For. Ser. Misc. Publ. 940, p. 83-89.

EHRLICH, W.A. 1970. The system of soil classification for Canada. Can. Dept. Agr. Ottawa, Queens Printer 249pp.

ENVIRONMENT CANADA. Atmospheric Environment Service. 1966-1972. Monthly record of meteorological observations in Canada. Downsview, Ont.

EWING, J. 1928. Plant succession of the brush prairie of northwestern Minnesota. J. Ecol. 12:238-265.

FRALISH, J.S. 1972. Youth, maturity and old age in aspen. USDA Gen. Tech. Rep. NC 1:52-58.

FULLER, G.D. 1923. An edaphic limit to forests in the prairie region of Illinois. Ecol.4:135-140.

GATES, F.C. 1930. Aspen association in northern lower Michigan. Bot. Gaz. 90(3):233-259.

GIFFORD, G.F. 1966. Aspen root studies on three sites in northern Utah. Amer. Midland Nat. 75:132-141.

GOODALL, D.W. 1973. Sample similarity and species correlation. In R.H. Whittaker, Ordination and classification of communities part V in Handbook of Vegetation Sci. ed. chief R. Tuxen. Dr. W. Junk The Hague, 10:

GRAHAM, S.A. HARRISON, R.P. and WESTELL, C.E. 1963. Aspens - phoenix trees of the Great Lakes region. Univ. of Mich. Press. 272pp.

HANSON, H.P. 1949. Post glacial forests in south central Alberta. Amer. J. Bot. 36:54-65.

HILTON, J.E. 1970. Forage production and utilization in the aspen parkland of Alberta following aerial application of 2, 4-D and 2,4,5-T. M.Sc. Thesis. Univ. Alberta. Unpublished. 122pp.

HILTON, J.E. and BAILEY, A.W. 1974. Forage production and utilization in a sprayed aspen forest in Alberta. J. Range Man. 27:375-380.

JEFFEREY, W.W. 1961. A prairie to forest succession in Wood Buffalo Park, Alberta. Ecol. 42:442-444.

JOHNSTON, A. and SMOLIAK, S. 1968. Reclaiming brushland in southwestern Alberta. J. Range Man. 21:404-406.

JOHNSTON, A., DORMAAR, J.F. and SMOLIAK, S. 1970. Long term grazing effects on fescue grassland soils. J. Range Man. 23:185-188.

KAURICHEV, L.S. and NOZDRUNOVA, E.M. 1969. General features of genesis of soils with temperate over moistening. In A. Gourevich, transl. A.A. Rode, ed. Advances in the theory of podzolization and solodization. Israel Program for Scientific Translation. Jerusalem, p. 42-57.

KIRBY, C.L., BAILEY, W.S. and GILMOUR, J.G. 1957. The growth and yield of aspen in Saskatchewan. Sask. Dept. Nat. Res. For. Branch Tech. Bull. 3:67pp.

KITTREDGE, J. 1938. The interrelationship of habitat, growth rate and associated vegetation in the aspen community of Minnesota and Wisconsin. Ecol. Mono. 8(2):151-246.

LESKIW, L.A. 1971. Relationship between soils and ground water in field mapping near Vegreville, Alberta. M.Sc. Thesis. Univ. Alberta. Unpublished.

LUTWICK, L.E. and DORMAAR, J.F. 1968. Productivity of a soil biosequence of the fescue priairie - aspen transition. J. Range Man. 21:24-27.

LUTZ, H.J. and CHANDLER, R.F. 1946. Forest soils. New York, Wiley and Sons. 514pp.

LYNCH, BROTHER DANIEL. 1955. Ecology of the aspen groveland in Glacier County, Montana. Ecol. Mono. 25:321-344.

MAINI, J.S. 1960. Invasion of grassland by *Populus tremuloides* in the northern Great Plains. PhD. Univ. of Sask. 231pp.

MAINI, J.S. 1968. Silvics and ecology of *Populus* in Canada. In J.S. Maini and J.H. Cayford. ed. Growth and utilization of poplars in Canada. For. Br. Publ. 1205:20-69.

Maini, J.S. and HORTON, K.W. 1966. Vegetative propagation of *Populus* spp. Influence of temperature on formation and initial growth of aspen suckers. Can. J. Bot. 44(9):1183-1189.

MAYCOCK, P.F. and CURTIS, J.T. 1960. The phytosociology of boreal conifer - hardwood forests of the Great Lakes region. Ecol. Mono. 30:1-35.

MEYER, D. 1956. The relation of soil horizon texture and acidity to the site index of aspen in northern Minnesota. Univ. of Minn. Agr. Expt. Sta. Scien. J. Series Paper 3574.

MOSS, E.H. 1932. The vegetation of Alberta. IV. Poplar association and related vegetation of central Alberta. J. Ecol. 20:380-415.

MOSS, E.H. 1938. Longevity of seed and establishment of seedlings in species of *Populus*. Bot. Gaz. 99(3):529-542.

MOSS, E.H. 1955. The vegetation of Alberta. Bot. Rev. 21(9):493-567.

MOSS, E.H. 1959. Flora of Alberta. Univ. of Toronto Press. 546pp.

MOSS, E.H. and CAMPBELL, J.A. 1947. The fescue grassland of Alberta. Can. J. Res. C25:209-227.

MUELLER-DOMBOIS, D. and ELLENBERG, H. 1974. Aims and methods of vegetation ecology. Wiley & Sons, New York.

MUNSELL, 1954. Soil color charts. Munsell Color Co. Inc. Baltimore, Md.

ORLOCI, L. 1966. Geometric models in ecology. I. The theory and application of some ordination methods. J. Ecol. 54:193-215.

ORLOCI, L. 1975. Multivariate analysis in vegetation research. Dr. W. Junk, Publ. The Hague. 276pp.

PETTAPIECE, W.W. 1969. The forest - grassland transition. In Pedology and quaternary Research. S. Pawluk ed. Symposium sponsored by Nat. Res. Coun. of Canada and Univ. of Alberta, p. 103-113.

PINCHBECK, B. 1972. Ordinational classification and statistical analysis of lakeshore vegetation. M.Sc. Thesis, Univ. of Alberta. Unpublished. 129pp.

SAINT CYR, J.B. 1903. Field notes of township 47, range 11, west of the 4th meridian. Dominion of Canada, legal land survey.

SANDBERG, D. and SCHNEIDER, A.E. 1953. The regeneration of aspen by suckering. Univ. of Minn., Minn. For. Note 24, 2pp.

SCHUYLENBORGH VAN, J. 1965. Formation of sesquioxides in soils. In E.G. Hallsworth and D.V. Crawford. Experi. Pedo. London, Butterworths, p. 113-123.

SHIRLEY, H.L. 1931. Does light burning stimulate aspen suckers? J. For. 29:524-525.

SHUL'GIN, A.M. 1965. The temperature regime of soils. A. Gourevich transl. Jerusalem. Israel Program for Scientific Translations, 218pp.

ST. ARNAUD, R.J. and WHITESIDE, E.P. 1964. Morphology and genesis of a chernozemic to podzolic sequence of soil profiles in Saskatchewan, Can. J. Soil Sci. 44:88-89.

STENECKER, G.A. 1972. Structure, size and development of trembling aspen clones in Manitoba. Ph.D. Univ. of Mich., Ann Arbour, Mich.

STOBBE, P.D. and WRIGHT, J.R. 1959. Modern concepts of the genesis of podzols. Soil Sci. Soc. Amer. Proc. 23:161-164.

STOECKELER, J.H. 1960. Soil factors affecting the growth of quaking aspen forests in the Lake states. Univ. of Minn., Agr. Expt. Sta. Tech. Bull. 233, 47pp.

STOECKELER, J.H. 1961. Organic layers in Minnesota aspen stands and their role in soil improvement. For. Sci. 7:66-71.

STRINGER, P. 1969. Ecological study of grasslands of low elevations in Banff, Jasper and Waterton Lakes National Parks. Ph.D. Thesis, Univ. Alberta.

STRUTHERS, P.H. and SIELING, D.H. 1948. Effect of organic anions on phosphate precipitation by iron and aluminum as influenced by pH. Soil Sci. 69:205-213.

SWAN, J.M.A., DIX, R.C. and WEHRHAHN, C.F. 1969. An ordination technique based on the best possible stand defined axes and its application to vegetation analysis. Ecol. 50(2):206-212.

TEAKLE, L.J.H. 1928. Phosphate in the soil solution as affected by reaction and cation concentrations. Soil Sci. 25:143-162.

TREWARTHA, G.T. 1968. An introduction to climate. New York. McGraw Hill, 407pp.

VIL'YAMS, V.R. 1968. Principles of soil science for agriculture. N. Kaner transl. H. Heimann ed. Israel Program Sci. Transl. Jerusalem, 447pp.

VOIGT, G.K., HEINSELMAN, M.L. and ZASADA, Z.A. 1957. The effect of soil characteristics on the growth of quaking aspen in northern Minnesota. Soil Sci. Soc. Amer. Proc. 21:649-652.

VOLOBUEV, V.R. 1964. Ecology of soils. A. Gourevich transl. Israel Program for Sci. Transl. Jerusalem, 200pp.

WIEGLE, W.G. and FROTHINGHAM, E.H. 1911. The aspens: their growth and management. U.S. Dept. Agr. For. Ser. Bull. 93, 35pp.

WILDE, S.A. and ZEHER, E.L. 1948. Influence of the ground water table upon the distribution and growth of aspen and jackpine in central Wisconsin. State Conserv. Dept. in co-op with Soil Dept. Coll. Agri. Tech. Note 30, Madison, Wisconsin.

WILDE, S.A. and PRONIN, D.T. 1949. Growth of trembling aspen in relation to ground water and soil organic matter. Soil Sci. Soc. Amer. Proc. 14:345-347.

WILLIAMS, W.T. 1971. Principles of clustering. In R.F. Johnston, P.W. Frank and C.S. Michener, Annual review of ecology and systematics. Vol. 2 Ann. Reviews, Palo Alto, p. 303-325.

WROE, R. 1971. Synecology of a *Festuca scabrella* grassland. M.Sc. Thesis. Univ. Alberta, 126pp.

WYATT, E.A., NEWTON, J.D. BOWSER, W.E. and ODYNSKY, W. 1944. Soil survey of Wainwright and Vermilion sheets. Univ. of Alberta Bull. 42.

ZAHNER, R. and CRAWFORD, N.A. 1965. The clonal concept in aspen stand relations. In C.T. Youngberg, ed. Forest soil relationships in North America. Papers pres. 2nd North Amer. Soils Conf. August 1963, Oregon State Univ. Corvallis, Oregon, p. 229-243.

ZALASKY, H. 1970. Disease problems of poplar in the western interior of Canada. Can. For. Ser. Dept. Fisheries and Inf. Report A-X-39, 33pp.

APPENDIX 1

Mean Cover Values of Important Species in the Main Community Types Recognized in Grove Two, 1970.

Community Type		s *Potr*/ *Syoc*(*Rowo*)	s *Potr*/[a] *Syoc* (*Rowo*)	m *Potr*/ *Syoc*(*Rowo*)	*Amal*	l *Potr*	s *Potr* (*Salix*)/ *Carex*	*Salix*/ *Carex*	s *Potr* / *Carex* (*Cal*spp.)
No. Samples		4	2	5	1	5	2	1	1
Species	Code								
Festuca scabrella [b]	*Fesc*	1	13			3			
Elaeagnus commutata	*Elco*	5	4			1			
Agropyron spp.	*Ag* sp.	1	1	1		7			1
Amelanchier alnifolia	*Amal*			8	98	4		1	
Smilacina stellata	*Smst*		1	7	3	4			1
Populus tremuloides	*Potr*	91	93	88	15	83	50	38	98
Rosa acicularis	*Roac*	10	11	18	3	19	7	1	15
Symphoricarpos occidentalis	*Syoc*	68	57	39	3	28		3	15
Viola adunca	*Viad*	5	5	7	3	11		1	3
Rosa woodsii	*Rowo*	45	43	36	1	14		15	38
Galium boreale	*Gabo*	9	5	2	3	1	1		3
Ribes oxyacanthoides	*Riox*	1	1	6	1	14		1	
Vicia americana	*Viam*	5	5	2		4	2	1	3
Fragaria virginiana	*Frvi*	8	7	7	1	7	1	15	1
Arenaria lateriflora	*Arla*	5	4	2	3	5	1	1	3
Taraxacum officinale	*Taof*	2	2	1	1	7	15	15	3
Carex spp.	*Carex*	12	27	11	3	22	74	85	85
Rubus strigosus	*Rust*	4	6	21	1	31	26	38	15
Anemone canadensis	*Anca*	5	6	5	1	6	1	3	15
Salix spp.	*Salix*		7	1	3	18	38	85	38
Aster hesperius	*Ashe*		3	1		2	8	3	15
Poa palustris	*Poapa*		8	1		1	19	38	38
Pyrola elliptica	*Pyel*				1	5		3	
Stachys palustris	*Stpa*		8			3	26	15	38
Mentha arvensis	*Mear*		7				15	15	38
Scutellaria galericulata	*Scga*		3			3	9	3	15
Calamagrostis spp.	*Cal* sp.					1		15	63
Sonchus arvensis	*Soar*		3				1	3	15
Ranunculus macounii	*Rama*						9	3	1
Geum allepicum	*Geal*	1	1				2	15	1

[a] This community type is a combination of s *Potr/Syoc (Rowo)* at grove edge and s *Potr/Carex* at slough edge and is included as a representative of the small *Potr* type recognized by the computer. i.e. this community type helps explain the position of small *Potr* on the X axis, relative to position of *Salix* and m *Potr* types.

[b] Only those species with five percent mean canopy coverage in at least one community type are included in Appendices 1 - 4.

APPENDIX 2

Mean Cover Values of Important Species in the Main Community Types Found in Grove Three, 1970.

Community Type		s *Potr/ Syoc*	m *Potr/ Syoc*	l *Potr/Syoc Carex(Ag* sp.)	l *Potr (Salix)/ Syoc*	*Salix(s Potr) Rust*/herb	*Salix/Rust/ Carex(Poapa)*
No. Samples		4	3	3	1	1	3
Species	Code						
Astragalus spp.	*As* sp.	1	5	1			
Festuca scabrella	*Fesc*	23	2	26		1	
Shepherdia canadensis	*Shca*			6			
Smilacina stellata	*Smst*	3	1	6	1	1	
Galium boreale	*Gabo*	5	5	6	1	1	
Populus tremuloides	*Potr*	95	85	85	85	38	7
Symphoricarpos occidentalis	*Syoc*	68	38	38	63	3	7
Rosa woodsii	*Rowo*	30	25	23	15	3	1
Agropyron spp.	*Ag* spp.	24	26	38	15	3	3
Aster laevis	*Asla*	5	15	23	15	1	1
Ribes oxyacanthoides	*Riox*	1	1	11	1	3	2
Achillea millefolium	*Acmi*	1	11	11	3	3	1
Arenaria lateriflora	*Arla*	1	5	2	3	3	1
Viola adunca	*Viad*	11	11	6	15		1
Fragaria virginiana	*Frvi*	23	11	7	15	3	23
Anemone canadensis	*Anca*	20	11	15	3	15	15
Taraxacum officinale	*Taof*	2	6	7	3	3	15
Rubus strigosus	*Rust*	10	11	10	15	38	55
Carex spp.	*Carex*	21	30	46	15	85	85
Poa spp.	*Poa* sp.	4	22	15	1	63	62
Geum allepicum	*Geal*	1	2	3	1	3	15
Stachys palustris	*Stpa*	1	6	6	1	15	15
Stellaria longifolia	*Stlo*	1		1	1	3	10
Bromus ciliatus	*Brci*	4	1	3			5
Pyrola elliptica	*Pyel*		3	7	3	1	1
Pyrola asarifolia	*Syas*		14	15	1		1
Salix spp.	*Salix*		1	23	63	63	77
Aster hesperius	*Ashe*		6	7	3	15	7
Epilobium angustifolium	*Epan*			1	1	1	7
Scutellaria galericulata	*Scga*			1	3	1	7
Calamagrostis	*Cal* sp.			2			15
Potentilla anserina	*Potan*			1		15	11
Cirsium arvense	*Ciar*			1		15	7
Mentha arvensis	*Mear*					15	15
Sonchus arvensis	*Soar*					63	18
Carex atherodes	*Caath*					38	15

APPENDIX 3

Mean Cover Values of Important Species in the Main Community Types Found in Grove Four, 1970.

Community Type		s *Potr/ Syoc*	m *Potr/ Syoc*	l *Potr/ Syoc*	*Salix*(l *Potr*)/ *Carex* (*Cal* sp.)	*Salix/ Carex*	*Syoc/ Carex*
No. Samples		4	5	2	1	2	1
Species	Code						
Festuca scabrella	*Fesc*	14					
Elaeagnus commutata	*Elco*	5		1			
Amelanchier alnifolia	*Amal*	4	29	9			
Lathyrus venosus	*Lave*	4	7	7			
Galium boreale	*Gabo*	6	2	3			
Viola adunca	*Viad*	5	5	9			1
Thalictrum venulosum	*Thve*	1	7	9	1		1
Ribes oxyacanthoides	*Riox*		1	15			1
Rosa acicularis	*Roac*			7			
Populus tremuloides	*Potr*	98	90	85	38	2	15
Symphoricarpos occidentalis	*Syoc*	74	52	61	1	26	38
Rosa woodsii	*Rowo*	26	41	27	15	15	15
Smilacina stellata	*Smst*	2	7	2	1	1	3
Arenaria lateriflora	*Arla*	5	2	2	1	2	1
Agropyron spp.	*Ag* sp.	13	2	3	3	1	15
Fragaria virginiana	*Frvi*	8	2	3	15	9	3
Anemone canadensis	*Anca*	5	7	9	15	9	3
Taraxacum officinale	*Taof*	1	1	1	3	3	15
Carex spp.	*Carex*	21	21	19	85	85	85
Rubus strigosus	*Rust*	13	16	9	15	20	15
Poa spp.	*Poa* spp.	4		1		38	38
Cornus stolonifera	*Cost*			9	3	8	3
Salix spp.	*Salix*			19	63	91	3
Aster hesperius	*Ashe*			1	3	8	15
Stachys palustris	*Stpa*				15	15	15
Geum allepicum	*Geal*				15	9	3
Calamagrostis spp.	*Cal* spp.				78	33	
Carex atherodes	*Caath*				38	15	15
Mentha arvensis	*Mear*				15	15	3
Stellaria longifolia	*Stlo*					15	3
Sonchus arvensis	*Soar*					8	3

APPENDIX 4

Mean Cover Values of Important Species in the Main Community Types Found in Grove Ten, 1970.

Community Type		s *Potr*/ *Syoc*	m *Potr*	l *Potr*	s *Potr*/ *Syoc* [(a)]	s *Potr*/ *Carex*	*Salix*(l *Potr*) *Rust*/*Carex*	*Salix*/ *Caath*
No. Samples		4	3	5	2	2	1	1
Species	Code							
Galium boreale	*Gabo*	3	6	7	3	1		
Viola adunca	*Viad*	5	6	2	4	1		
Smilacina stellata	*Smst*	1	11	8	1	1		
Lathyrus ochroleucus	*Laoc*	1	1	8	1		1	
Ribes oxyacanthoides	*Riox*		2	7			3	
Populus tremuloides	*Potr*	88	98	62	91	98	38	
Symphoricarpos occidentalis	*Syoc*	57	23	17	38		3	3
Rosa woodsii	*Rowo*	18	23	15	12	2	3	15
Fragaria virginiana	*Frvi*	11	6	10	10	7	3	3
Taraxacum officinale	*Taof*	2	1	2	6	15	15	3
Anemone canadensis	*Anca*	4	3	7	4	3	15	3
Rubus strigosus	*Rust*	21	15	20	23	26	63	15
Carex spp.	*Carex*	24	11	31	33	50	63	15
Arenaria lateriflora	*Arla*		1	4	3	8	1	3
Salix spp.	*Salix*		5	13	6	15	63	98
Stachys palustris	*Stpa*			2	3	9	15	15
Rosa acicularis	*Roac*			6	1	2	3	15
Geum allepicum	*Geal*			2	3	9	15	3
Poa palustris	*Poapa*			7	9	26	38	15
Aster hesperius	*Ashe*			4		1	15	3
Mentha arvensis	*Mear*			4	5	15	15	15
Sonchus arvensis	*Soar*			1	1	3	15	3
Carex atherodes	*Caath*			3	9	26	15	63
Calamagrostis spp.	*Cal* sp.			3	3	7		15
Stellaria longifolia	*Stlo*				1	3	3	15

[a] This s *Potr/Syoc* is the community resulting from a combination of s *Potr/Syoc* at grove edge and s *Potr/Carex* at slough edge. It is this median community calculated by the computer that helps to position the small *Potr* plots on the X axis between *Salix* and medium *Potr* instead of at the end most distant from *Salix*.

APPENDIX 5

Mean Cover Values (%) for Important Species in Secondary Clusters of Grove Two, 1971

Plot Number / Species	17	15	16	12	11	24	20	28	21	25	26	18	23	12	27	19	10	22	14
Viola adunca[a]	33																		
Rosa woodsii	21										26				19				
Pyrola asarifolia				16															
Shepherdia canadensis									19										
Amelanchier alnifolia											28								
Thalictrum venulosum								15							13				
Ribes oxyacanthoides		24	11	20				22			13								
Populus tremuloides	88	74	85	58	83	95	43	51				31	55				37		
Symphoricarpos occidentalis	15	49	21				29	10			10		24		12				
Rubus strigosus	15	18	44			25	29						33	36		14			
Calamagrostis spp.			12			13						12	20						
Carex spp.			36		35	69		43			33	18	25	50			40		32
Rosa acicularis				58			12		62					19				15	
Salix spp.				14		21						37	91	30	43	33	80	95	73
Populus balsamifera										21					59				
Poa spp.						42					11			26					
Mentha arvensis						10					15						12		
Carex atherodes										33						21		37	
Sonchus arvensis																	17		

[a] Species with 10 percent canopy cover in at least one plot.

APPENDIX 6

Mean Cover Values for Important Species in Secondary Clusters of Grove Three, 1971.

Plot Number	13	14	11	10	12	16	9	15	8
Species									
Festuca scabrella[a]	79	74	35	11					
Agropyron spp.	50	56	57		68				
Populus tremuloides		68	88	52	86	85	91		
Carex spp.	38	74	61	13	34	61	40	15	28
Poa spp.	17	17	13						14
Fragaria virginiana	10	33						15	
Viola adunca					22				
Rubus strigosus					21	75		68	
Salix spp.						17	52		39
Pyrola elliptica						17			
Aster hesperius						13			
Pyrola asarifolia				17					
Symphoricarpos occidentalis				17			26		
Cornus stolonifera							18		
Poa palustris								45	
Sonchus arvensis									35
Carex atherodes									17

[a] Species are included that have 10 percent canopy coverage in at least one plot.

APPENDIX 7

Mean Cover Values for Important Species in Secondary Clusters of Grove Four, 1971.

Plot Number / Species	7	16	17	19	18	20	8	12	9	5	6	15	10	11	14
Cornus stolonifera[a]	18								26						
Rosa acicularis	<u>70</u>			<u>44</u>											
Rosa woodsii						11									
Lathyrus venosus			47												
Thalictrum venulosum				32											
Ribes oxyacanthoides	10			10											17
Amelanchier alnifolia				26			24								
Populus tremuloides	<u>98</u>	<u>98</u>	<u>98</u>	<u>79</u>	<u>95</u>	<u>46</u>	28	12	12	<u>85</u>	<u>40</u>				
Symphoricarpos occidentalis				16	15	23	12	<u>58</u>	12						26
Carex spp.			26	<u>46</u>	28	23		<u>40</u>	<u>62</u>	20	40		31	<u>79</u>	
Poa spp.		<u>40</u>										15		13	
Rubus strigosus				10		30									
Rubus pubescens							25						30		
Calamagrostis spp.		33						14		<u>87</u>	42	<u>50</u>	<u>51</u>	22	
Salix spp.					31					35		<u>48</u>	<u>83</u>	<u>95</u>	<u>88</u>
Fragaria virginiana										44	<u>51</u>				
Poa palustris										12	45				
Aster hesperius												10	16		
Sonchus arvensis													12		
Stellaria longifolia														11	
Stachys palustris														11	

[a]Only species with 10 percent canopy coverage in at least one plot are included.

APPENDIX 8

Mean Cover Values for Important Species in Secondary Clusters of Grove Five, 1971.

Plot Number	17	13	16	15	9	14	12	10	11
Species									
Amelanchier alnifolia [a]		71							
Rosa acicularis	11			21					
Festuca scabrella	38		49						
Schizachne purpurascens		30							
Agropyron spp.			24						
Lathyrus venosus			27		31				
Cornus stolonifera				63					
Populus tremuloides	98	86	45	89	85	83	98	50	
Symphoricarpos occidentalis	79	63	68	24	10			35	
Calamagrostis spp.					24			68	62
Lonicera dioica					22				
Carex spp.						37	23		10
Salix spp.						40			
Populus balsamifera							36		95
Rubus pubescens								22	
Epilobium angustifolium									14

[a] Only species with 10 percent canopy coverage in at least one plot are included.

APPENDIX 9

Mean Cover Values for Important Species in Secondary Clusters of Grove Eight, 1971.

Plot Number / Species	17	16	12	13	18	15	14	6	9	7	8	10	19	11
Elaeagnus commutata (a)	16													
Viola adunca		29												
Agrostis scabra		12												
Festuca scabrella	<u>86</u>				24		10							
Amelanchier alnifolia						19				54				
Ribes oxyacanthoides								<u>46</u>						
Fragaria virginiana	<u>79</u>	<u>44</u>		<u>26</u>									17	
Rosa woodsii			15						31		16	<u>44</u>		
Thalicturm venulosum			35			34	20						11	
Populus tremuloides	<u>98</u>	<u>98</u>	<u>98</u>	<u>85</u>	<u>69</u>	<u>48</u>	<u>39</u>	<u>59</u>	<u>40</u>					
Symphoricarpos occidentalis			10	<u>85</u>		31	17	12	<u>68</u>	22	<u>41</u>	<u>68</u>	<u>56</u>	
Carex spp.	24	<u>49</u>	22		<u>51</u>		20		16	10	<u>56</u>	33	15	
Taraxacum officinale				20										
Poa palustris					33									
Rubus strigosus						10			12			29		
Rosa acicularis						11	<u>56</u>	16		25			10	
Lathyrus ochroleucus										16		38		
Salix spp.														<u>91</u>
Carex atherodes														<u>63</u>

[a]Only species with 10 percent canopy coverage in at least one plot are included.

APPENDIX 10

Mean Cover Values for Important Species in Secondary Clusters of Grove Ten, 1971.

Plot Number / Species	15	14	9	10	7	8	13	16	11	12
Agropyron spp.[a]		24								
Rosa woodsii			57							
Festuca scabrella				16						
Solidago gigantea		43		12			15			
Populus tremuloides			91	59	62	54	23	50		
Symphoricarpos occidentalis	33	45	44	74	22					
Rubus strigosus	10		11		29	19				
Carex spp.		10			42	83			19	33
Poa palustris						24				
Anemone canadensis						11				
Aster laevis							15			
Hedysarum alpinum							13			
Fragaria virginiana								13		
Salix spp.								55	17	33
Rosa acicularis									41	12
Rubus pubescens									23	35
Ribes oxyacanthoides										22
Smilacina stellata										12

[a] Only species with 10 percent canopy coverage in at least one plot are included.

APPENDIX 11

Description of Selected Soil Profiles from Six Groves, 1971

Plot Number / Soil Type	Vegetation Type / Horizon	Depth[a]	Color M	Color D	Gleying	Structure	Consistence (dry)	Texture	Roots
8N6	s *Potr/Syoc (Rowo)*[a]								
Orthic Dark Brown Chernozem	LH	2-0	10 YR						
	Ah	0-18	2/2	4/2		mod f gr[b]	sl hd	L	ab
	Bm	18-58	4/3	4/2		mod f-m gr	sl hd	SCL	pl
	Cca	58+							
10E5	m *Potr/Syoc*								
Calcareous Dark Brown Chernozem	LH	2-0	10 YR						
	Ah	0-30	2.5/2	2/2		mod m-f gr	sl hd	L	ab
	Bmk	30-56	4/3	4/3		mod m-f gr	sl hd	CL	pl
	Cca								
8S6	s, m *Potr/Syoc*								
Gleyed Dark Brown Chernozem	LH	2-0	10 YR						
	Ah(g)	0-28	2/2	3/2	f fi fa	mod f gr	sl hd	L	ab
	Bm_1g	28-46	4/3	4/3	m me dis	st f sab	hard	CL	few
	Bm_2g	46-81	4/3		m me pr	st f-m gr	hard	CL-SCL	v few
	Ccag	81+							
8E5	s *Potr/Syoc (Amal)*								
Orthic Black Chernozem	LH	2-0	10 YR						
	Ah	0-20	2/1	3/1		mod f gr	sl hd	SCL	ab
	Bm	20-43	4/2	5/3		mod f-m gr	sl hd	SCL	pl
	Cca	43+	5/3			mod f gr	sl hd	CL	few

Appendix 11 (continued)

Plot Number / Soil Type	Vegetation Type / Horizon	Depth	Color M	Color D	Gleying	Structure	Consistence (dry)	Texture	Roots
10S5	*Salix* (s *Potr*)								
Calcareous	LH	1-0	10	YR					
Black	Ah	0-15	2/1	2/1.5		mod f gr	soft	SCL	ab
Chernozem	Bmk	15-56	2.5Y	4/4		mod c gr	sl hd	CL	pl
	Cca	56+							
3S6	s *Potr/Fesc* (*Carex*, *Ag* spp.)								
Carbonated	Ah	0-15	2/1	3/2		mod f gr-	s-fib	SCL	ab
Rego Black	Ahk(g)	15-51	2/2	3/2	f fi fa	fib	sl hd	CL	ab
Chernozem	Ccag	51+	10	YR	c fi dis	mod f gr			
5S4	s,m *Potr/Amal*								
Gleyed	LH	2-0	10	YR					
Rego Black	Ahg	0-20	2/1	2/2	m fi fa	mod m-f gr	soft	SCL	pl
Chernozem	ABkg	20-25	2/1	2/2	m fi dis	mod m-f gr	s-sl hd	SCL	ab
	Ckg	25-58	4/2	5.5/ 2.5	m me pr	mod m-f gr	s-sl hd	SCL	few
10W4	m *Potr* (*Salix*)								
Carbonated	LH	2-0	10	YR					
Gleyed	Ah	0-13	2/2	2/2		w f gr	soft	CL	ab
Rego Black	Ahgk	13-56	2/2	2/2	c fi dis	w f gr	soft	CL	pl
Chernozem	Ccag	56+	variable		m me pr	w f gr	sl hd		few
8W6	s *Potr/Syoc*								
Orthic	LH	5-0	10	YR					
Dark	Ahe	0-30	2/2	3/1		mod f gr	sl hd-hd	L	ab
Grey	AB	30-36	4/3	5/3.5		w f sab-m gr	hard	SCL	pl
Chernozem	Btj	36-84	4/3	5/3		mod f sab	hard	CL	pl
	Cca	84+							

Appendix 11 (continued)

Plot Number / Soil Type	Vegetation Type / Horizon	Depth	Color M	Color D	Gleying	Structure	Consistence (dry)	Texture	Roots
4E4	s ,m *Potr*								
Carbonated	LH	5-0	10	YR					
Dark	Ahe	0-38	2/2	3/2		w sab-powder	sl hd	SL	ab
Grey	ABk	38-61	2/2	3/1		mod f pl-pow	sl hd	L-SCL	few
Chernozem	Bmk	61+	3.5/2	5/3		mod f gr-pow	sl hd	L-SCL	
5N3	m *Potr/Syoc*								
Gleyed	LH	2-0	10	YR					
Dark	Ahe(g)	0-36	2/2	2/1	f fi-me	mod f gr	sl hd	L	pl
Grey	Btjg	36-56	3/3	4/3	c fi dis	mod f sab	sl hd-hd	CL	few
Chernozem	Ckg	56+			m fi pr			SCL	
2W4	m *Potr*								
Orthic	LH	5-0	10	YR					
Dark	Ahe	0-20	3/2	3/2		mod f gr	sl hd	SCL	ab
Grey	Ae	20-28	3/3	6/3		mod c gr-powder	sl hd	CL-SCL	few
Luvisol	Bt	28+	3/3	3/4		mod f ab	v he	CL	few
4W4	m *Potr/Roac*								
Gleyed	LH	5-0	10	YR					
Dark	Ah	0-5	1.7/1	2/1		w f gr-powder	soft	SL	ab
Grey	Ahe	5-13	3/2	4/2	f fi fa	w f pl-powder	sl hd	SL	ab
Luvisol	Ae	13-20	5/3	6/3	f fi fa	w f pl-powder	sl hd	SL	v f
	Btg	20-58	4/3	5/4	f-c fi dis	mod f sab	hard	SL-SCL	few
	Ck	58+							

Appendix 11 (continued)

Plot Number / Soil Type	Vegetation Type / Horizon	Depth	Color M	Color D	Gleying	Structure	Consistence (dry)	Texture	Roots
4S3	m *Potr/Syoc*								
Carbonated	LH	5-0	10	YR					
Dark	Ahek	0-46	2/2	2/2		w f gr-powder	soft	L-SL	ab
Grey	Aek	46-56	5/3	6/2		w f pl-powder	soft	CL-SCL	few
Luvisol	Btjk	56+	4/3	5/3		mod f gr	soft	CL	v f
3N4	m *Potr/Roac*								
Orthic	LH	4-0	10	YR					
Gleysol	Aheg	0-8	3/2	3/2	c fi-me dis	mod f gr	sl hd	SCL	ab
	Bgtj	8-36	3/3	4/3	m fi-me pr	st f sab	hard	CL	pl
	Ccag	36+	3/3	4/3				CL	few
3E4	1 *Potr/Carex*								
Orthic	LH	5-0	10	YR					
Humic	Ahg	0-20	2/2	3/1	c fi dis	mod f gr	sl hd	SCL	ab
Gleysol	Bgtj	20-53	3/2	3/3	m fi-me pr	mod f sab	hard	SCL	pl
	Ccag	53+							
3S4	m *Potr*								
Rego	LH	5-0	10	YR					
Humic	Ahg	0-30	2/1	3/1	f fi dis	mod f gr	sl hd	SCL	ab
Gleysol	ACkg	30-46	5/3	6/2	m fi pr	w md-f gr-f	soft	CL	pl
	Ccag	46+			m fi-me pr				

Appendix 11 (continued)

Plot Number / Soil Type	Vegetation Type / Horizon	Depth	Color M	Color D	Gleying	Structure	Consistence (dry)	Texture	Roots
3W4	m, 1 *Potr*								
Carbonated	LH	2-0	10	YR					
Humic	Ahejg	0-30	2/1	3/1	f fi fa	mod f gr	sl hd	SCL	ab
Gleysol	Btjgk	30-51	3/2	4/2	c fi dis	st f sab	hard	CL	few
	Ccag	51+	5/3	4/3	m fi-me pr	st m gr	hard	CL	v f
8S1	*Salix/Carex atherodes*								
Orthic	LH	2-0	10	YR					
Humic	Aheg	0-18	3/1	4/1	f fi fa	mod f gr+w pl	sl hd	L	ab
Eluviated	Aeg	18-36	5/2	6/1	f fi dis	w f pl-powder	sl hd	L-SL	few
Gleysol	Btg	36+	4/34	4/3	m fi-me pr	st f sab	hard	CL	v f
2E3	1 *Potr/Roac*								
Carbonated	LH	5-0	10	YR					
Humic	Aheg	0-15	2/1	3/1	f fi dis	w f pl-f gr	s-sl hd	L-SCL	ab
Eluviated	Aeg	15-20	4.5/1	7/1	f fi dis	st f pl-powder	s-sl hd	SCL	few
Gleysol	Btgk	20-71	4/2	5/3	m fi-me pr	mod m gr-vf	sab sl hd-hd	CL	pl
	Ckg	71+							

Appendix 11 (continued)

Footnotes:

[a] Vegetation code: *Potr* = *Populus tremuloides* (s - small 0-8.9 cm DBH; m - medium 9.0-17.8 cm DBH; l - large >17.8 cm DBH), *Syoc* = *Symphoricarpos occidentalis*, *Roac* = *Rosa acicularis*, *Rowo* = *Rosa woodsii*, *Carex* = *Carex* spp., *Fesc* = *Festuca scabrella*, *Amal* = *Amelanchier alnifolia*, *Ag* spp. = *Agropyron* spp., *Salix* = *Salix* spp.

[b] Abbreviations: mottles - m = many, c = common, f = few, fi = fine, me = medium, fa = faint, dis = distinct, pr = prominent

structure - grade: w = weak, mod = moderate, st = strong
class: f = fine, m = medium, c = coarse
kind: gr = granular, ab = angular blocky,
sab = sub angular blocky,
pl = platey, fib = fibrous
consistence - s = soft, sl = slightly hard, hd = hard, vhd = very hard, fib = fibrous
texture - S = sand, L = loam, C = clay
roots - ab = abundant, pl = plentiful, f = few, vf = very few
color - M = moist, D = dry.

[c] Btjk moist color is 2.5 YR, dry is 10 YR.

[d] Btg moist color is 2.5 YR, dry color is 10 YR.

APPENDIX 12

Mean Cover Values (%) of Important[a] Species of the Six Main Clusters, 1970.

Cluster number		5	1	4	2	6	3
Cluster		*sPotr*[b] */Syoc/ Fesc*	*s,mPotr/ Syoc(Rowo)*	*lPotr (Salix)/ Syoc*	*lPotr*	*Salix(s,lPotr)/ Rust/Carex*	*Salix/Rust/ Carex (Poa* spp.*)*
N =		2	27	2	7	2	4
Species	Code						
Festuca scabrella	*Fesc*	38.0	1.8				
Amelanchier alnifolia	*Amal*	7.5	1.3	1.5	0.6		
Galium boreale	*Gabo*	15.0	5.3	2.0	3.1		
Thalictrum venulosum	*Thve*	0.5	1.9	8.0	2.1		
Pyrola asarifolia	*Pyas*	0.5	1.1	8.0	2.3		0.7
Agropyron spp.	*Ag* spp.	26.5	3.2	15.0	0.4		2.2
Symphoricarpas occidentalis	*Syoc*	74.0	57.7	63.0	9.3	2.0	14.7
Populus tremuloides	*Potr*	98.0	92.7	85.0	67.6	38.0	5.5
Rosa woodsii	*Rowo*	15.0	36.3	26.5	11.1	2.0	4.7
Viola adunca	*Viad*	9.0	7.9	9.0	1.0	0.5	0.7
Ribes oxyacanthoides	*Riox*	1.5	1.4	8.0	9.0	2.0	1.7
Carex spp.	*Carex*	15.0	16.4	9.0	34.7	63.0	85.0
Geum allepicum	*Geal*	0.5	0.6	1.0	1.7	9.0	15.0
Anemone Canadensis	*Anca*	19.5	6.8	2.0	3.7	9.0	12.0
Taraxacum officinale	*Taof*	3.0	1.6	3.0	3.4	15.0	12.0
Fragaria virginiana	*Frvi*	26.5	7.4	9.0	6.6	3.0	17.7
Poa spp.	*Poa* spp.	7.5	0.8	0.5			56.0
Smilacina stellata	*Smst*		4.7	8.0	4.7		0.5
Rosa acicularis	*Roac*		2.7	7.5	7.3	9.0	0.2
Stachys palustris	*Stpa*		0.4	1.0	1.9	15.0	15.0
Salix spp.	*Salix*		1.1	50.5	17.7	50.5	82.2
Aster hesparius	*Ashe*		0.4	1.5	3.4	15.0	5.5
Rubus strigosus	*Rust*		15.9	15.0	13.3	39.0	50.5
Sonchus arvensis	*Soar*				1.0	9.0	14.2
Carex atherodes	*Caath*				7.6	7.5	15.0
Mentha arvensis	*Mear*				4.9	15.0	15.0

[a]Species with greater than five percent mean canopy cover in at least one cluster.

[b]*Populus tremuloides* size classes s - small 0 - 8.9 cm DBH; m - medium 9.0 - 17.8 cm DBH; l - large greater than 17.8 cm DBH.